European Environment Agency

Ecosystem Accounting for the Cost of Biodiversity Losses: Framework and Case Study for Coastal Mediterranean Wetlands

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"Because National Accounts are based on financial transactions, they account for nothing Nature, to which we don't owe anything in terms of payments but to which we owe everything in terms of livelihood."
Bertrand de Jouvenel, Arcadie, 1968

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Introduction: Accounting for biodiversity loss

1. Ecosystem services and biodiversity loss

The way people are thinking about biodiversity is changing. For a long time the main arguments made for the conservation of species and habitats has been based on issues such as their evolutionary uniqueness, their rarity, or on the extinction threat they may face. Today, the argument that we need to maintain the biodiversity that we find on earth is also being made in terms of how it directly benefits people – that is how biodiversity contributes to their well-being or quality of life. Once we focus on this important link, questions about the costs of biodiversity loss to Society become paramount.

One way of looking at the relationships between biodiversity and the benefits that people gain from ecological systems is in terms of what is known as ***ecosystem services.*** These are services which fundamentally depend on the properties of living systems, ranging from individual species to habitats. They cover such things as the ***production*** of food and fibre, the ***regulation*** of natural processes such as flooding, and the ***cultural*** qualities of which help define an area's 'sense of place', and which can be important for recreation and tourism. The significance of such ecosystem services for human well-being has been highlighted by the publication in 2005, of the Millennium Ecosystem Assessment (MA), which reported that at global scales, 60% of the services examined in the study (15 out of 24) are being degraded or used unsustainably. Human activities have been responsible for most of the damage – largely through the effects it has had on the biodiversity and the integrity of ecological systems. Box 1 describes in more detail the types of ecosystem services recognized in the Millennium Ecosystem Assessment, and the way they have changed in the recent past.

2. What is biodiversity loss?

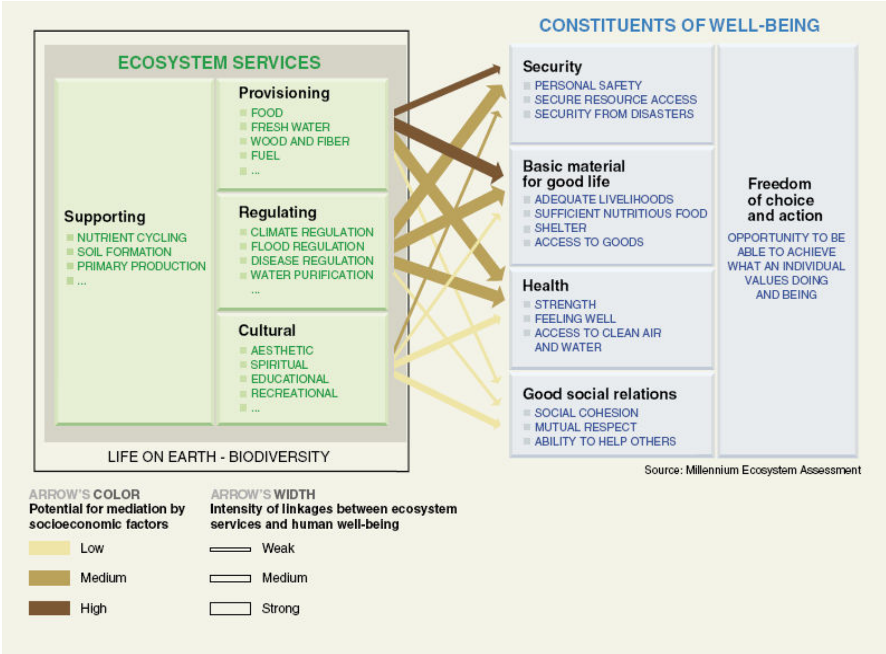
The term biodiversity is used to describe a number of different things. Often it is used to refer to the richness of living organisms in an area. In this context, biodiversity loss can simply mean the reduction in numbers in a plant or animal population found in an area or in the most extreme cases, their extinction. However, the term biodiversity loss can mean other things too. It can also refer to the genetic diversity within populations, and the diversity of habitats and ecological communities in which species occur. We depend on the structure of these ecosystems and the ecological processes that operate within them for the production, regulation and cultural services on which people depend. Human impact can undermine or change the productivity of ecosystems, the way nutrients cycle within them, or alter the balance between different species groups, so that the capacity of these systems to deliver ecosystem services is undermined. Thus biodiversity loss does not only mean the loss of species, but also the loss of ecosystem functioning (Box 2).

The output of ecosystem services for society therefore depends on both the range and ***quantity*** of ecosystems and their ***quality***. Taken together, the quality and quality of ecosystems determines their capacity to generate the benefits for people. Understanding the implications of biodiversity loss is as much about tracking the way in which the quantity and quality of ecosystems change over time, as describing in scientific terms the links between living organisms and the services they provide.

Ecosystem Accounts can help us to do this. They are tools that we can use to describe systematically how the quantity and quality of ecosystem ecosystems and the ecological structures and processes that underpin them, change over time. Ultimately they can help us understand the costs of such change to people, either in monetary terms or in terms of risks to their health or livelihood.

Box 1: The Millennium Ecosystem Assessment Approach and Key Findings

The MA highlighted the links between ecosystem services and the elements of human well being in the graphic below. The strength of the arrows indicates the importance of different aspects of the relationship.



The MA went on to look at the way the key services had changed historically through a series of global and sub-global assessments. The results are summarised as follows:

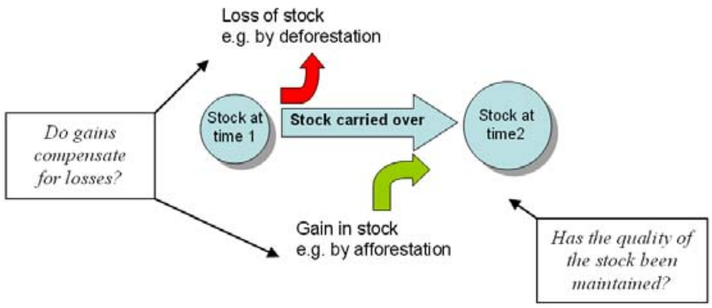
Service	Sub-category	Status	Notes
Provisioning Services			
Food	crops	▲	substantial production increase
	livestock	▲	substantial production increase
	capture fisheries	▼	declining production due to overharvest
	aquaculture	▲	substantial production increase
	wild foods	▼	declining production
Fiber	timber	+/–	forest loss in some regions, growth in others
	cotton, hemp, silk	+/–	declining production of some fibers, growth in others
	wood fuel	▼	declining production
Genetic resources		▼	lost through extinction and crop genetic resource loss
Biochemicals, natural medicines, pharmaceuticals		▼	lost through extinction, overharvest
Water	fresh water	▼	unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating Services			
Air quality regulation		▼	decline in ability of atmosphere to cleanse itself has declined
Climate regulation	global	▲	net source of carbon sequestration since mid-century
	regional and local	▼	preponderance of negative impacts
Water regulation		+/–	varies depending on ecosystem change and location
Erosion regulation		▼	increased soil degradation
Water purification and waste treatment		▼	declining water quality
Disease regulation		+/–	varies depending on ecosystem change
Pest regulation		▼	natural control degraded through pesticide use
Pollination		▼*	apparent global decline in abundance of pollinators
Natural hazard regulation		▼	loss of natural buffers (wetlands, mangroves)
Cultural Services			
Spiritual and religious values		▼	rapid decline in sacred groves and species
Aesthetic values		▼	decline in quantity and quality of natural lands
Recreation and ecotourism		+/–	more areas accessible but many degraded

An upwards arrow indicates that the condition of the service globally has been enhanced and a downwards arrow that it has been degraded

Supporting services, such as soil formation and photosynthesis, are not included here as they are not used directly by people.

This report illustrates how we can use them to look the resources wetland ecosystems provide. It pays particular attention to coastal wetlands in the Mediterranean basin. It will show how ecosystem accounts provide a basis for developing policy and a framework for looking at different management options and strategies. Although the focus of the report is wetlands, this approach can be applied to all types of ecosystem. In the long term we will need them to make

Box 3: The 'Accounting Model'



*If ecosystems are regarded as assets that provide benefits to people, then we can think of describing them, and the way they change of over time, in terms of an 'account' similar in structure to those used to calculate our financial situation. Over time the stock or **quantity** of a habitat may change as a result of the balance between the processes that destroy or restore it, and the **quality** of the stock carried over may change as the functionality of the system is transformed by other impacting factors or pressures. Accounts are a way of describing these changes in both in physical terms using different kinds of indicator of ecosystem integrity and health, and ultimately in terms of the monetary values we place on these assets and the changes in stock*

sure that society takes better account of ecosystem services and the biodiversity that gives rise to them, and that the value of these services are included in our decision making (Box 3).

3. Wetlands and the services they provide

Wetlands are a particularly important ecosystem in which to look at in order to explore how the costs of biodiversity loss to Society take better account benefits they provide in our decision making.

Table 1 (after Schuyt, and Brander, 2004)

Total Economic Value of Global Wetlands by Continent and Wetland Type (thousands of US$ per year, 2000)

	Mangrove	Unvegetated. Sediment	Salt/Brackish Marsh	Freshwater Marsh	Freshwater Woodland	TOTAL
N America	30,014	550,980	29,810	1,728	64,315	676,846
Latin America	8,445	104,782	3,129	531	6,125	123,012
Europe	0	268,333	12,051	253	19,503	300,141
Asia	27,519	1,617,518	23,806	29	149,597	1,818,534
Africa	84,994	159,118	2,466	334	9,775	256,687
Australasia	34,696	147,779	2,120	960	83,907	269,462
TOTAL	185,667	2,848,575	73,382	3,836	333,223	3,444,682

Globally, wetlands supply an important flow of ecosystem services that contribute to human well-being. These services include not only food, freshwater and building materials, but also protection from flooding and coastal erosion, carbon storage and sequestration, and opportunities for tourism. Many wetland areas have enormous cultural significance for people. Although is hard to quantify it has recently been suggested[1] that a ‘conservative’ estimate of their value be around $3.4 billion per year (Table 1).

[1] Schuyt, K. and Brander, L (2004) *Living waters: Conserving the source of life. The economic values of the world’s wetlands.* WWF, Gland, Switzerland. Prepared with the support of the Swiss Agency for the Environment, Forests and Landscape (SAEFL).

Table 2: Services associated with Mediterranean Coastal Wetlands

Provisioning	***Food***	**Hunting prays** **Food gathering** **Fishing** **Seafood** *Livestock* *Agriculture* *Aquiculture*
	Materials	*Fresh water* *Salt works* *Construction materials ("Arids")* *Fiber crops* *Tree plantations*
	Forest related	**Timber** **Fuel / wood** Cork Pines
	Plant-related	**Genetic resources** **Medicinal & cosmetic plants**
	Physical support	*Communication* *Housing*
Cultural	***Amenity***	**Recreation** **Tourism/Ecotourism** **Landscape beauty**
	Identity	*Sense of place* *Cultural heritage* *Religious / spiritual*
	Didactic	**Education / interpretation** **Scientific research** **Traditional Ecological Knowledge**
Regulating	***Cycling***	**Soil retention & Erosion control** **Hydrological regulation** *Saline equilibrium* **Pollination for useful plants** **Climate regulation**
	Sink	**Soil purification** **Waste treatment** **Water purification**
	Prevention	**Flood buffering** **Pest prevention** **Invasive species prevention** **Air quality**
	Refugium ***Breeding***	**Habitat maintenance** **Food web maintenance** **Nursery**

Note: Those services shown in bold show a strong and direct relationship to biodiversity. Those in italics have weaker links and are more associated with the physical, social and cultural characteristics of the area.

At global scales wetlands represent a very diverse set of ecosystems, providing many different types of service. In this report we focus only on the coastal systems found in the Mediterranean basin. Table 2 list some of the important services that have been identified in this study as important in these areas. The classification broadly follows the approach of the MA, although we have refined it to highlight those which show a particularly strong link to biodiversity. These are the ones most sensitive to biodiversity loss and in this report we have focused upon them to examine what kinds of cost might be arise if the integrity of the ecological systems that underpin them is undermined.

Although the wetlands of the Mediterranean Basin are only a small subset of all wetlands, they nevertheless provide an important and valuable case study in which the ecosystem accounting approach can be developed and tested. In Europe we are relatively well placed in terms of the data resources available to describe these systems, and the analytical resources needed foe the present work can be mobilised relatively quickly. It is important to note, however, that the approach to describing and understanding the consequences of biodiversity loss and ultimately the costs that loss have for society is a generic one, which can be applied both to wetlands elsewhere and any other ecosystem on which people depend.

At global scales wetlands are amongst the most threatened ecosystems as a result of drainage, land reclamation, land conversion, pollution, and overexploitation, and those found in the Mediterranean are no exception. As a result it has been estimated that more than half of all Mediterranean wetlands have been lost (IUCN, 2002)[2]. Salt marshes, for example, have been progressively ‘reclaimed’ and converted to arable or industrial land. Nevertheless, many important areas remain, and in some areas people’s livelihoods are closely linked to the health and integrity of coastal wetland systems, particularly in southern Mediterranean countries. Along the North African coast, for example, *MedWet*[3] reports that fish and shellfish remain a significant source of protein for many people, and that in many other part of the Mediterranean, fishing for direct household consumption or for sale in local markets is still a common place.

4. The causes of biodiversity loss and the loss of ecosystem services

The Millennium Ecosystem Assessment explains the reasons for biodiversity loss and its impact on ecosystem services in terms of *indirect* and *direct* drivers of change. Indirect drives are broad-scale influences such as climate change or agricultural markets that, in the context of biodiversity and ecosystem services, change environmental conditions or the way people and society behave. The direct drivers are the more immediate influences on that affect the distribution, structure and dynamics of ecological systems, say through land management decisions.

Wetlands are amongst the most productive and biodiverse terrestrial habitats *(Ref…MA chapter inland water)*. They are also amongst the most sensitive to the various direct and indirect drivers of change. Coastal wetlands are amongst the most sensitive. It has been estimated[4], for example, that generally about 30 to 50% of the area of Earth’s major coastal environments have been degraded in the last 20 years *(check?)*, a loss which far exceeds those suffered by the tropical forests – largely as a result of the pressure that such areas are under in terms of human use and development, and the vulnerability of these systems to outside factors.

There are many examples from the wetlands of Europe which illustrates just how quickly they can be degraded, with a consequent impact on human well-being. The major drivers of change

[2] IUCN (2002) Integrated Water Management to Address Environmental Degradation in the Mediterranean Region.

[3] http://www.medwet.org/medwetnew/en/04.RESOURCE/04.1.wetlandfacts01.html

[4] See Valiela and Fox (2008) Science, 319, 290-291; and C. Duarte, Ed., *Global Loss of Coastal Habitats* (Fundación BBVA, Madrid, 10 October 2007). A video of the conference is available at www.fbbva.es/coastalhabitats.

include the loss of the sediment needed to sustain them through the damming of rivers that supply them, the over-use of water upstream and changes in their hydrology, land use changes which have resulted in the draining of large areas of land and its conversion for intensive agricultural production or urban development, eutrophication and pollution, the introduction of alien species as well as overharvesting of fish stocks and the general loss of the biodiversity associated with such areas due to the modification of habitats.

In wetlands, the effects of these drivers of change on human well-being and prosperity include: the increased vulnerability of human populations to flooding as the water storage capacity of wetland areas is diminished; the loss of wetland areas as 'nutrient sinks' that help buffer and purify the waters entering the marine system; the loss of wildlife areas and their associated recreational potential. As we face the problem of dealing with climate change, the loss of wetland areas has also diminished services such as carbon storage that might be important for our future.

Wetland ecosystems might be particularly sensitive to the direct and indirect pressures arising from the impacts of human development and environmental change – but they are not unique in this respect. Many of the ecosystems that we find both in Europe and other parts of the world are under such pressures, and if we are not in the long term to lose the benefits they currently or could in the future provide, we need better ways of monitoring their fate, and using this type of information more effectively in our decision making. Ecosystem accounting is one such tool, and in this Report we explain just how it can be used.

5. Linking Biodiversity, Ecosystem Services and People

The study of the links between biodiversity and ecosystem services is a relatively new field. It is also a particularly challenging one because it requires us to connect up different disciplines and integrate understandings across a range of subject area. A exciting new idea that arises once we start to think about the connection between ecological processes and the needs of people is that we have to think of ecosystems in much broader ways – that is as coupled social and ecological systems – that is socio-ecological systems (SES) (Folke et al. 2003)[5]. These systems are said to be 'coupled' because each component depends on and influences the other. And if we are to understand how they work, we need in investigate in detail how people interact and shape the environment thorough their management actions and cultural practices, as well as looking at the underlying biophysical processes themselves. The task is a particular challenging one, because as Erikson (2007) notes[6], despite their mutual dependencies, the interactions between the social and ecological components and highly uncertain and unpredictable outcomes.

Wetlands in Europe provide us with some particularly good examples of these 'cultural landscapes' and are therefore especially valuable in helping us to think some of these ideas through. This report will show how socio-ecological systems can be defined and mapped, and how we can use them an accounting units within which we can begin to understand the costs of biodiversity loss.

[5] Folke, C., Colding, J., Berkes, F., 2003. Synthesis: building resilience and adaptive capacity in social–ecological systems. In: Berkes, F., Colding, J., Folke, C. (Eds.), Navigating Social–Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge.

[6] Ericksen, P.J., (2007) Conceptualizing food systems for global environmental change research. *Global Environmental Change* doi:10.1016/j.gloenvcha.2007.09.002

As we look at ecosystems in general and the importance of the link between biodiversity and the services that the environment provides it is important to distinguish those services which have a stronger or weaker link to the activities and characteristics of living organisms. For example, many coastal wetlands in Europe, such as the Camargue, are important for the production of salt. The industry depends on the evaporation of saline waters in the lagoons of the delta, and while this fundamentally depends on natural processes, it is not really an ecosystem service in the strict sense of the word – more a service provided by a particular type of landscape. The mechanisms that generate most *ecosystem services* have at their core 'biodiversity' that is living organisms that are responsible for, or support the output of, some benefit to people.

An especially important challenge that anyone interested in looking at the links between biodiversity and ecosystem services is how change in biodiversity affects the delivery of any particular service. The mechanisms and relationships linking the different ecological elements that give rise to the service can be complex, and so we cannot assume that there is a simple and direct relationship between the two. Understanding these relationships, or what some people call these 'production functions', is key to successfully calculating the costs of biodiversity loss.

The kinds of issue that arise when looking at the links between biodiversity and service output is illustrated by recent work on coastal ecosystems in Thailand[7]. It had been assumed, for example, that the value of the output of ecosystem services, such as shrimp farming, costal protection, wood and fish products from coastal ecosystems such as mangroves, salt marshes, sea grass beds, near-shore coral reefs, and sand dunes was related to the area of these habitats in a simple linear way. Instead it was found (Box 4) that if the wave attenuating characteristics of these areas are taken into account, the value of the services for different kinds of beneficiary changed in a non-linear way, such that the rate of increase in value was much less at larger areas. The conclusion from this study was that if the relationships were indeed like this then it may have profound implications for land use decisions when seeking to reconcile the needs of conservation with those of development.

The coastal ecosystems of Thailand, like the wetlands of the Mediterranean, described in this study, are good examples of systems that can provide many services to people at the same time. These *multifunctional ecosystems* present particular challenges for managers and policy makers, because it if often difficult to reconcile the different needs that people have for the services associated with them or to calculate the exact costs of biodiversity loss though its impact on the different service systems that might depend upon them.

Chapters 1 and 2 of this report look at the ways in which we can represent the multiple services that may be associated with an area of wetlands, as part of a much wider discussion about how we characterise services and value them. Ultimately economic valuation of ecosystem services can help decision makers to identify the main trade-offs among ecosystem services and how they might be viewed by different stakeholder groups. For example, the introduction of *Eucalyptus* in Mediterranean wetlands for paper production has impacted on aquifers and hence water supply in these areas. As a result, it has been decided in some places that these plantations should be eliminated – but this may lead to the loss of income from honey producers, whose bees use them as an important nectar source.

[7] Barbier et al. (2008) Coastal Ecosystem–Based Management with Nonlinear Ecological Functions and Values, *Science*, 319, 231-233.

Box 4: Values of shrimp farming in Thailand as a function of mangrove area under different assumptions about wave attenuation effects of wetlands of different sizes (after Barbier et al., 2008).

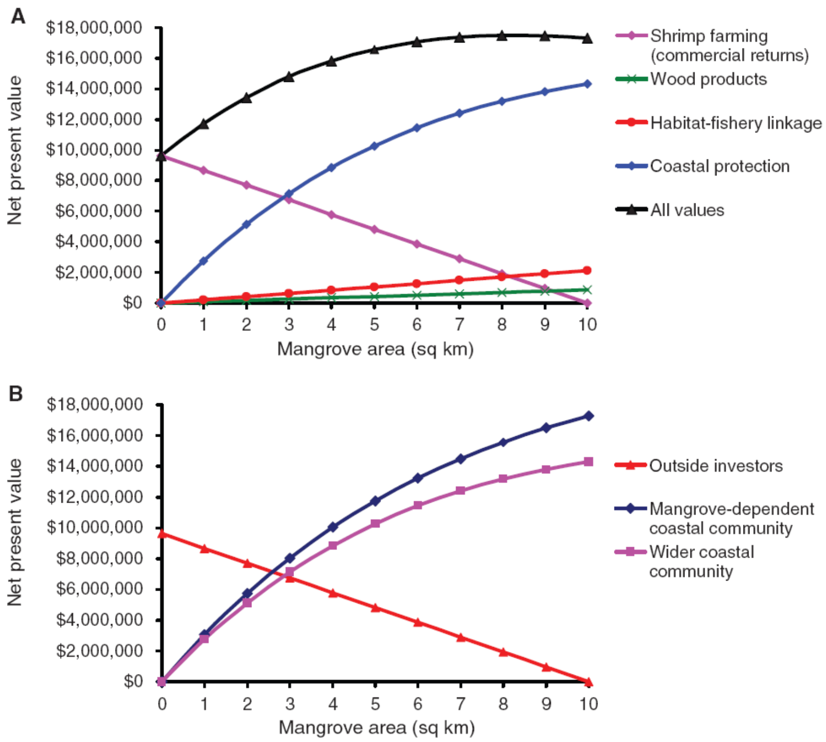


Fig. 2. Alternative comparison of shrimp farming to various mangrove services at coastal landscape level (10 km^2), Thailand (calculated as in Fig. 1), incorporating the nonlinear wave attenuation function from fig. S1A, on the basis of (**A**) total economic returns as a function of mangrove area (km^2) for the commercial returns from shrimp farming plus three mangrove ecosystem service values: coastal protection, wood product collection, and habitat support for offshore fisheries; and (**B**) the distribution of benefits as a function of mangrove area (km^2) among three stakeholders: outside investors in shrimp farms, the mangrove-dependent coastal community, and the wider coastal community (up to 5 km away).

Explain results further…

6. The Ecosystem Approach and ecosystem accounting

The Ecosystem Approach (EsA) emerged as a focus of discussion in the international policy community who were concerned with the management of biodiversity and natural resources in the 1980s and early 1990s. It was suggested that a new focus for decision making was needed that would deliver more integrated policy and management that had previously been achieved. The idea has now come to be a central element of the Convention for Biological Diversity (CBD), which in 1995 adopted it as the 'primary framework' for action (IUCN, 2004). According to the CBD, the EsA:

> *"….places human needs at the centre of biodiversity management. It aims to manage the ecosystem, based on the multiple functions that ecosystems perform and the multiple uses*

that are made of these functions. The ecosystem approach does not aim for short-term economic gains, but aims to optimize the use of an ecosystem without damaging it.'[8]

A decade on, challenge we still to face is to find effective ways of describing to managers, policy makers and the people who own or use different kinds of ecosystem, how these multiple functions relate to each other, how they are changing and what significance these changes might have. A key theme promoted in the principles formulated by the CBD is that decision making should take full account of the value of ecosystem services. The land and ecosystem accounting framework described in this study is one way that this can be done.

Land and Ecosystem Accounts can be used to represent changes in our 'natural capital' in the same way that economic accounts can be used to monitor changes in the monetary wealth of organisations and countries. They operate in much the same way as conventional monetary accounts, in that we try to represent the stocks of different ecosystem elements, and processes that affect them, and how these changes affect the flow of benefits or service that arise from them. The concept is one that has been actively developed by the EEA for Europe[9], and is one that is central to the development of integrated economic and environmental accounts being promoted by the UN[10]. Much of the background to this work is summarised in Chapter 1 of this Report.

Broadly, Land and Ecosystem Accounts let us look at the 'asset stocks' that ecosystems represent and service or 'benefit flows' that they generate in two ways. First, most straight-forwardly, simply in terms of the physical units that are used to measure them. Thus the stock of a wetland ecosystem can be described in terms of its area, or a resource such as the population of a species that might be in terms of numbers or density. Similarly the production, regulating or cultural services that the system generates can be represented in terms of, say, the tons of fish harvested per day, the amount of carbon stored per year, or the annual number of visits to an area by people for recreational activities.

The second way that ecosystem accounts can represent asset stocks and flows is in monetary terms. This is, however, by no means easy, because of the nature of many of the ecosystem services themselves, and the attempt to devise robust ways to make such valuations is now a major focus of debate in both the research and policy communities.

The reason why it is important to try to put monetary values on ecosystem services is that we might more easily compare them. This is particular useful when dealing with multifunctional systems, like wetlands, where ecosystems give rise to a whole bundle of benefits – and we might want to see how the value of the total package changes in the light of some development or external pressure. It also makes the comparison between different areas a little easier. However, the task of monetary valuation is made difficult, however, because many ecosystem services are not traded we cannot use this kind of information as a guide to the worth of an ecosystem.

Production services are perhaps the easiest to deal with, since they are often commodities in themselves, which can be traded in some kind of market, or at least they are part of commodities that are. However, not all production services can be valued in this way. Throughout the world, for example, many the food wetlands generate underpin the subsistence livelihoods of farmers and fisherman. Even in Europe, the 'informal' or 'wild foods' that wetlands provide can be of great significance culturally. These types of service, like most regulation and cultural services are generally referred to as 'non-market' services, and to value them other approaches are needed.

[8] http://www.iucn.org/themes/CEM/ourwork/ecapproach/index.html

[9] EEA (2006), *Land accounts for Europe 1990-2000, Towards integrated land and ecosystem accounts*, EEA Report No 11/2006 http://reports.eea.europa.eu/eea_report_2006_11/en

[10] UN, EC, IMF, WB, OECD, *Integrated Environmental and Economic Accounting (SEEA2003)*, UN Statistical Division, New York, 2003. http://unstats.un.org/UNSD/envAccounting/seea2003.pdf

Chapter 2 of this report describes how we can handle these types of service and value them in greater detail.

The valuation of ecosystem services is a complex issue, both for those who attempt to make such calculations and those who use the results in decision making. Certainly estimates of the value of wetlands, like those shown in Table 1 should be considered carefully. A number of points need to be made about them. First, their accuracy is highly dependent on the quality of the underlying biophysical data that underlies them – for example unless we have robust estimates of the area and condition of different wetlands, then it is impossible to accurately 'scale up' to aggregated values from individual case studies. For example, Schuyt, and Brander, (2004) suggest that the total, annual value of wetlands could be as high as $70biooion/year , if the estimate of the global area of wetlands used in the *Ramsar* Convention is used. One of the contribution that ecosystem accounting can make is that it can help provide a systematic and consistent set of biophysical data on which estimates of value can be built.

A second point that needs to be made about the estimates of value like those shown in Table 1, is that they are heavily dependent on the sorts of information people have available to them at the time estimates are made. For example, wetlands are now valued much more highly because of the services they offer in terms of carbon storage and sequestration now than they were a decade or so ago, because of what we now know about the possible impacts or likelihood of climate change. Physical accounts thus provide something of a more 'constant basis' on which estimates of value can be based as people's attitudes and needs change.

Thirdly, such figures cannot be used simply to suggest that this would be cost of biodiversity loss, if these ecosystems were totally destroyed or transformed by human action. The figures themselves are annual estimates for the value of outputs, and the total costs would be much higher since this level of income would be lost every year there after. The scale of the loss that is calculated depends on how we value or 'discount' the future. As Chapter 3 of this report explains, perhaps the best way of using estimates of value is to look at them in terms of the relative or marginal changes different decision making strategies or scenarios describing alternative plausible futures. This type of analysis can help us understand the changes in the costs of maintaining the outputs from ecosystems and people's well-being in the face of the direct and indirect drivers that impact upon them.

Because many ecosystem services have no simple market value, these ecosystems are often not given sufficient consideration in decision-making. The final point that needs to be made about estimates such as those shown in Table 1, are that they are probably underestimates, because not all of the services associated with them were used in the calculations. What ever the case, it is clear that as a result, because we do not always know even how the relative values of ecosystems might change, the effects of direct and indirect pressures on these systems that can lead to their degradation and destruction are not managed. Their full costs to society are never calculated. While traditionally in the context of wetlands decision-making has only considered the value of those ecosystem services that have a markets value, today it is more widely acknowledged that the non-market benefits that they provide must be taken into account. The approach to ecosystem accounting described in this report shows how this can be done.

7. How do we calculate the costs of biodiversity loss?

Whether we use physical or monetary units to describe the ecosystem stocks and service flows, accounts are essential for calculating the *costs* of biodiversity loss to society. Even if we cannot put a monetary value to the decline in some service such as flood protection, a change in, say, flood frequency can be quantified and its implications for people or communities considered. Moreover, even if society finds it difficult to put a precise monetary value on the total outputs of services from an ecosystem, it is possible to look at the costs of restoring ecosystem function or maintaining it as part of the debate that decision makers and stakeholders must have when looking at future options. In this report, therefore, we take a very broad interpretation of what ‘costs’ mean.

Thus in constructing ecosystem accounts we have sought to describe both the quantity and quality of ecosystem assets in physical terms, and to use new types of indicator to identify how the health of these systems is changing under different types of external pressure. These indicators of ecosystem health can also be used to look at the effectiveness of restoration efforts. In order to make the results as useful as possible, however, we also make a first attempt to estimate the costs of protection and restoration. This is an important basis for accounting and provides a framework for subsequent forecast studies – because in looking at the question of the costs of biodiversity loss we need to know how these costs might change under a range of possible futures. For example, on the basis of the evidence provided by the case studies covered in this Report, we might consider the relative benefits of eliminating the effects of current European Agriculture Policies which encourage the intensification of land use in wetland areas, or the effects of adopting new measures to control water extraction, overharvesting, or encourage greater stakeholder participation in management decisions.

Report will therefore be of direct relevance to the ‘Stern-like review’ for biodiversity loss, in that it will not only provide an example of the impact that human activities have had on an ecosystem that is important and valuable in its own right, but also describe an evolving methodological framework that will be an essential tool for decision makers in the future.

CHAPTER 2: Biodiversity focus

2.1. Biodiversity and ecosystem services

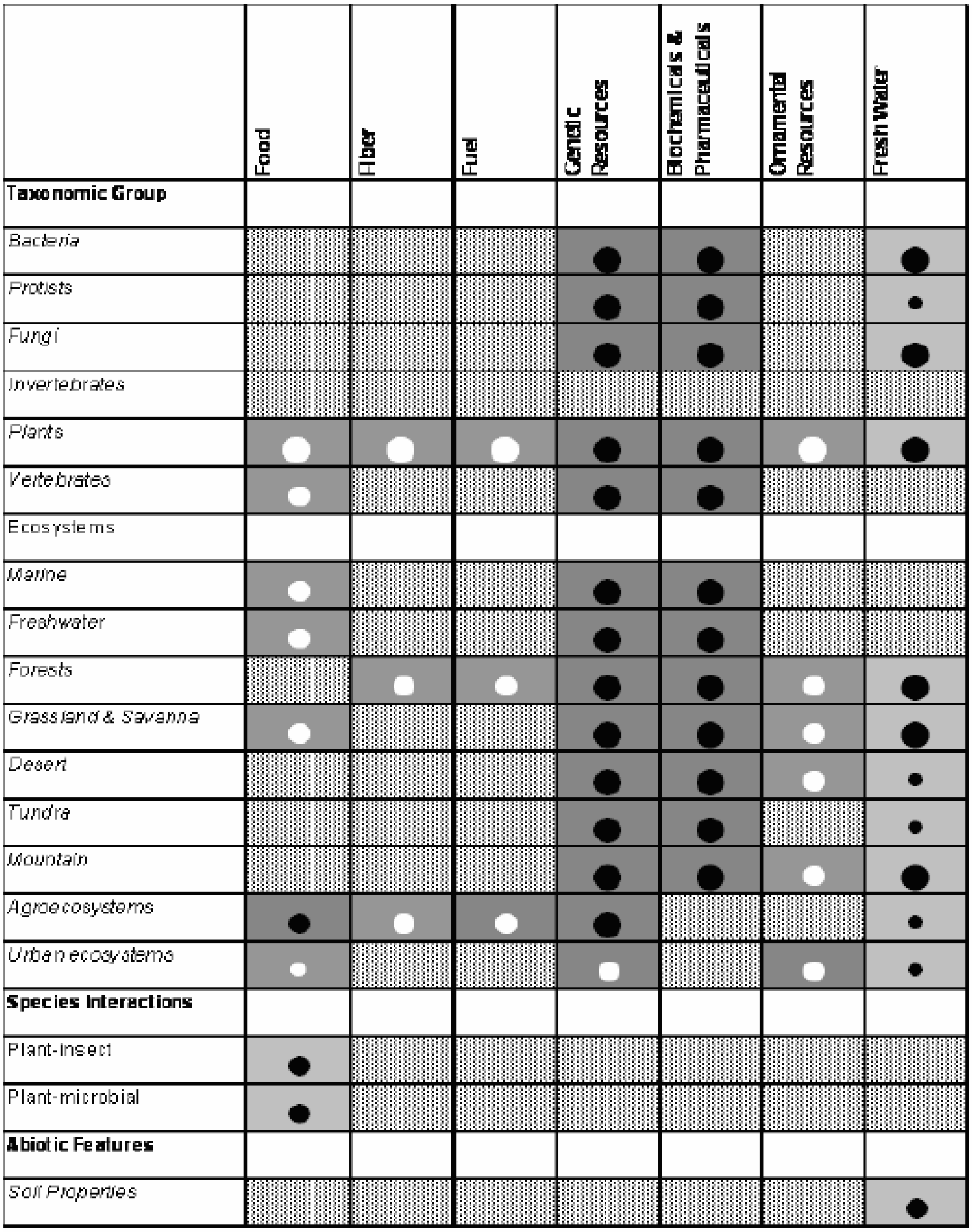
The relationship of biodiversity and ecosystem services is complex and its complexity multiplies when they are subjected to economic valuation and accounting. Variety and variability of life forms usually at species level is treated as one of the services of healthy and well functioning ecosystem provide. However, ecosystems and biodiversity also generate a wide range of other services through its bio-geo-chemical processes that are critical for sustenance of humans. An ecosystem, which is a dynamic complex of plant, animal and microorganism communities and other nonliving environment interacting as a functional unit, provides services which sustain, strengthen and enrich various constituents of human well being. Human well being here refers to a set of basic materials for a good life, freedom to act and make choices, good social relations and security.

2.2. Measurement of key biodiversity-dependant ES

As noted in the Introduction to this Report, the MA took an ecosystem service perspective, because its focus was management of ecosystem for enhancing human well being and poverty reduction. In this context, biodiversity did not appear explicitly as a service, unless it was at the species level, where is could be treated as part of provisioning services, associated, for example with, cultivated, forest or, marine ecosystems. Nevertheless, the importance of biodiversity for human well-being should not be overlooked.

The complexity of the relationship between ecosystem services and biodiversity should be seen in the larger canvass of forces of ecosystem dynamics and its responses to human pressure, biodiversity and its thresholds, economic, technical and institutional factors interplaying among themselves and ever evolving. Recent research has attempted to shed some light on some aspect of this complexity (Hooper et al, 2005; Spehn et al, 2005 and Dirzo and Loreau, 2005). The picture, at least to economist and decision makers attempting valuation and accounting for effective response strategy, remains unclear though. Kinzig, Scholes and Perrings (2007) show the importance of species in maintaining ecosystem services and final benefits (Figure 1).

Fig1: The importance (symbol size), number of species involved (black, white) and degree of redundancy (cell shade) of species or ecosystems involved in supplying provisioning services



In Figure 1, the black and white dots show the importance of biodiversity. Black suggests that all the species in the indicated categories are required, while white shows some redundancy among the species for the services described. The background shows current state of knowledge among scientists. Dark grey indicates high proportion of all species within this category should be conserved, mid grey shows some redundancy and white shows high level of redundancy.

Therefore considering the complexity of understanding the consequences of biodiversity loss it would be safest to approach the valuation of ecosystem services via the goal of an integrated account of ecosystem services and conventional economic sectors. From the accounting perspective, valuation of provisioning, cultural and regulating services entering into consumption and production spheres would be appropriate. That in no way reduces the importance of biodiversity and "supporting services" which are the primary inputs to all other services, but it avoids the danger of double counting when making any aggregated cost estimates.

The unique feature of most of the services emanating from ecosystems is that altogh their importance is acknowledged by people, they are often unaccounted for, unpriced and outside the domain of the market. In conventional parlance, such problems are treated as externalities where markets fail. In these situations, decision makers try to correct the failure by creating market like situation by attempting to obtain the value of services through various valuation techniques based on stated preference of the people.

In case of regulating services such climate, waste treatment capacity, nutrient management and various watershed functions, classic situations of market failure are common (Bator, 1954). Such difficulties are particularly problematic where the consequences of market failure and biodiversity loss fall upon the most vulnerable sections of society, especially in developing countries, where many people depend upon them for their livelihood. As a result, there has in recent years, been an added focus on creating a situation where market can be created so that desirable outcomes can be achieved in terms of implications of different decisions culminating through the impact on ecosystems and in turn human well being (Costanza et al, 1995). Thus valuation issues have thus increasingly become central to debates about conservation of both biodiversity and ecosystem services.

Valuation of ecosystem service is not meant merely to show the importance of ecosystem to the society but rather to enable decision makers to evaluate alternative courses of action and thus clarify the dilemmas that arise out of being faced with conflicting choices. Valuation of ecosystem services helps the decision making process in the following ways:

i. Market and non market valuation methods for valuation of ecosystem services can capture some of the 'out of market' services.
ii. Valuation can help the decision makers in situations of trade-off and in exploring alternative courses of action
iii. Valuation has the potential to 'clear the clouds of conflicting goals' in terms of political, social and economic feasibility of the policies, although it might not be the last word.
iv. Valuation enables may enable extended Cost Benefit Analysis (CBA).

v. It enables green accounting as per SEEA2003 (UNSD)

vi. In the context of sectoral and project policies, valuation of ecosystem services may strengthen the environmental impact assessment and the make the appraisal criteria more acceptable, transparent and credible.

There have in recent years been concerted attempts to value ecosystem services. Some have been targeted towards terrestrial ecosystem services (Daily et al 1997), a few have focussed on marine ecosystem (Duarte, 2000). Some studies have tried to capture the value of all types of ecosystem and services at the global scale (Costanza et al, 1997; Limburg and Folke, 1999; Woodward and Wui, 2001). These studies have drawn the attention of not only researchers but also practitioners and conservation managers. However, they have not been free of criticism, especially in terms of uncertainty associated with estimates (Winkler), and the methods used to revelations of preference (Allen and Loomis). One of the most serious criticisms that have arisen in relation to these studies concerns the way they have used the benefit transfer method and replacement costs approach. Following (Freeman1998), the latter, the replacement costs approach should only be used if:

a. Human engineered system (HES) provide the same quantity and quality of services;
b. HES is the least cost option; and,
c. Aggregates of individuals would be willing to incur those costs.

If any of the above conditions are not met, then estimates might not be convincing for decision makers and be unhelpful in any robust economic analysis. As critiques of recent studies suggest (e.g. \$2.928Tr by Pimentel for the US biodiversity; \$53Tr of World's Ecosystem Services by Costanza et al. 1997) the values derived may not be credible

Valuation of ecosystem requires consistent and logical steps of identification of key services, bio physical data, monetization and aggregation as shown in the Figure 2:

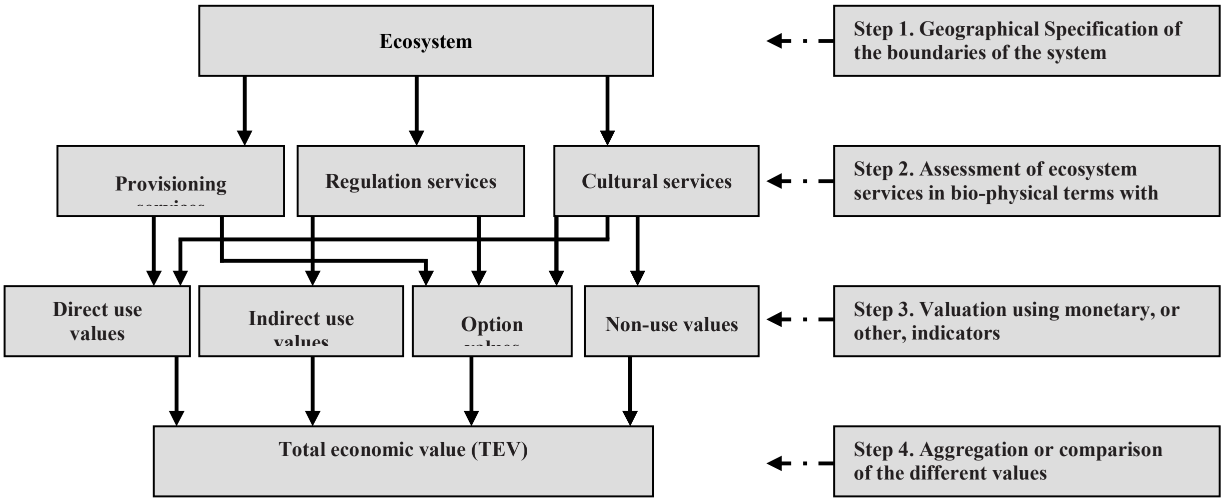


Figure 2: The Ecosystem valuation framework. The solid arrows represent the most important links between the elements of the framework. The Dashed arrows indicate the four principle steps in the valuation o Ecosystem services (Hein et al..2006)

2.3. Valuation of biodiversity-dependant ES: principles and examples

One of the main reasons why scientists and decision makers are worried about the loss of ecosystems is that they provide valuable services and there are strong indications that these services have been degraded considerably in last 50-60 years (MA, 2005). For example, more land was converted to cropland since 1945 than in the 18th and 19th centuries combined, 25% of the world's coral reefs have been badly degraded or destroyed in the last two or three decades, and 35% of mangrove area has been lost in roughly the same time (MA, 2005). The question then arises is how valuable the services are that are associated with these ecosystems. We need to be able to answer this question to inform the choices we make in relation to how we manage these ecosystems in the future.

Economic valuation attempts to answer these questions. Valuation provides insight into the losses (or gains) across different stakeholders, arising out of perturbations in ecosystems and subsequent services. Such work ensures that choices are better informed by assessing looses and gains, which are very important for evaluating the contribution of public policies. The general approach is based on the fact that human beings derive benefit (or "utility") from the use of ecosystem services either directly or indirectly, whether currently or in the future.

However, several important aspects of this valuation paradigm need to be stressed:

- The utility that an individual human being derives from a given ecosystem service depends on that individual's preferences. The utilitarian approach, therefore, bases its notion of value on attempts to measure the specific utility that individual members of society derive from a given service, and then aggregates across all individuals, weighting them all equally.

- Utility cannot be measured directly. In order to provide a common metric in which to express the benefits of the very diverse variety of services provided by ecosystems, the utilitarian approach attempts to measure all services in monetary terms. This is purely a matter of convenience, in that it uses units that are widely recognized, saves the effort of having to convert values already expressed in monetary terms into some other unit, and facilitates comparison with other activities that also contribute to societal well being. It explicitly ***does not mean*** that only services that generate monetary benefits are taken into consideration in the valuation process. On the contrary, the essence of almost all work on valuation of environment and ecosystems has been to find ways to measure benefits which do not enter markets and so have no directly observable monetary benefits.

Valuation of ecosystem services for costs benefit analysis or integrated ecosystem accounting under SEEA calls for an interdisciplinary effort from both economists and ecologists. While the production and asset boundary should be carefully defined and the distinction between intermediate and final outputs from of ecosystems clearly defined, the initial condition of the ecosystem and the beneficiary's preference must also be clearly identified. Some of the popular valuation methods, its approach and applications have been summarised in Table 1.

Table2: Application of Main Economic Valuation Techniques

Methodology	**Approach**	**Applications**
Change in productivity	Trace impact of change in environmental services on produced goods	Any impact that affects produced goods (e.g. declines in soil quality affecting agricultural production)
Cost of illness, human capital	Trace impact of change in environmental services on morbidity and mortality	Any impact that affects health (e.g. air or water pollution)
Replacement cost	Use cost of replacing the lost good or service	Any loss of goods or services (e.g. previously clean water that now has to be purified in a plant)
Travel cost method	Derive demand curve from data on actual travel costs	Recreation, tourism
Hedonic prices	Extract effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits (e.g. the higher market value of waterfront property, or houses next to green spaces)
Contingent valuation	Ask respondents directly their willingness to pay for a specified service	Any service (e.g. willingness to pay to keep a local forest intact)
Choice modelling	Ask respondents to choose their preferred option from a set of alternatives with particular attributes	Any service
Benefits transfer	Use results obtained in one context in a different context	Any service for which suitable comparison studies are available

Studies on valuation of ecosystem services also suggest that there needs to be an integrated effort if successful valuation is to be achieved. Some of the emerging lessons are:

a) Valuing ecosystem services requires integrating ecology and economics, with ecology providing insights into hoe services are generated, and economics establishing the relative worth of services through market and non-market valuation techniques.

b) Joint effort necessary: studies of ecologists and economists need to link together to get estimates of value of ecosystem services. For example, by asking such questions as 'what quantity (quality) of services is produced under various possible states of the ecosystem?' or 'as human actions, deliberate or unintended, change ecosystems, how is the production of ecosystem services changed?'.
c) Valuation of ecosystem services has to be context specific, ecosystem specific and guided by the perception of beneficiaries.
d) Total valuation evaluates whole catchments, landscapes, or mapping unit, while marginality valuation evaluates the incremental changes in ecosystem services as a consequent of measured pressure on the ecosystem in consideration.
e) More and more focus should be on the valuation of marginal changes of ecosystem rather the value of 'total' ecosystem.
f) Initial condition and state of the ecosystem is important in valuation of ecosystems.
g) Valuation should be done for ecosystem services assuming they are independent of each other
h) Establishing property rights for the ecosystem is critically important for valuation.
i) While doing valuation, issues of irreversibility and resilience must be kept in mind.
j) Clear cut biophysical linkages and relationships not only facilitate the valuation exercise but also ensure its credibility in public policy debates.
k) Uncertainty is one of the key challenges in valuation of ecosystem services and therefore a sensitivity analysis would be liked by the decision makers.
l) Participatory exercises improve the representativeness of the sample, ensuring participation, and embedding outcomes in the institutional processes would enable the valuation more authentic and acceptable to the decision makers.
m) Valuation has the potential to clarify issues relating to conflicting goals in terms of political, social and economic feasibility of the policies but it might not be the 'last word' on the matter.

While ecosystem valuation is certainly difficult, the choice of not doing it is not open to us. The valuations are essentially about assigning relative weights to the various aspects or circumstances when making a decision. When we value the services of ecosystems, and decision-makers take these values into account when making policies, a framework for distinguishing and grouping these values is required. The context of valuation of ecosystem services, its purpose and appropriateness of methodology are the key considerations. Pagiola et al. (2004) summarize the approach, rationale and methodological framework for exercise in the way given in the table below**:**

Table 3: Valuation of Ecosystem Services-When, Why and How

Approach	Why do we do it?	How do we do it?
Determining the total value of the current flow of benefits from	To understand the contribution that	Identify all mutually compatible services provided: measure the quantity of each

an ecosystem.	ecosystems make to society.	service provided; multiply by the value of each service.
Determining the net benefits of an intervention that alters ecosystem conditions	To assess whether the intervention is economically worthwhile.	Measure how the quantity of each service would change as a result of the intervention, as compared to their quantity without the intervention; multiply by the marginal value of each service.
Examining how the costs and benefits of an ecosystem (or an intervention) are distributed	To identify winners and losers, for ethical and practical reasons.	Identify relevant stakeholder groups; determine which specific services they use and the value of those services to that group (or changes in values resulting from an intervention).
Identifying potential financing sources for conservation	To help make ecosystem conservation financially self-sustaining.	Identify groups that receive large benefit flows, from which funds could be extracted using various mechanisms.

(Source: Pagiola, 2004)

Several issues pertinent to valuation of ecosystem services and application to decision making have emerged, especially with a better understanding of the mechanisms of ecosystem functioning. The relevance of the state of ecosystem functioning has not been given adequate emphasis in derivation of ecosystem values, thereby rendering the values derived of little worth when one is examining especially issues related to sustainability.

In order to provide true and meaningful indicator of the scarcity of ecosystem services and functions, economic valuation should account for the state of ecosystem. Though, ecosystems can recuperate from shocks and disturbances, through an inherent property of resilience, there are several circumstances when the ecosystem shifts to an entirely new state of equilibrium (Holling, 2001). Standard economic theory based concepts deriving ecosystem values using marginal analytic methods are limited to situations when ecosystems are relatively intact and functioning in normal bounds far away from any bifurcation (Limburg et al, 2002). This is of particular significance to developing countries, wherein significant trade-offs exist between conservation and economic development, and decisions often favour the latter. Therefore, decisions made on the basis of a "snapshot" ecosystem value can provide false policy directives.

The second issue primarily deals with aggregation of individual values to arrive at larger values, viz. "*societal values*". Ecosystem goods and services, by definition, are public in nature, meaning that several additional benefits accrue to society as a whole, apart from the benefits provided to the individuals (Daily, 1997; Wilson and Howarth, 2002). The theoretical fundamentals of development of economic valuation methodology rest on the axiomatic approaches of individual preferences and individual utility maximization, which does not justify the public good characteristic of ecosystem services. Valuation methodologies, such as contingent valuation, utilize individual preferences as a way of deriving values and these may be used for resource allocation where these goods are largely public in nature. A considerable body of recent literature therefore favours adoption of a discourse-based valuation (Wilson and Howarth, 2002). The primary focus of discourse-based valuation approach is to come up with a consensus societal value of scarcity indicator, derived through a participatory process, to be used for allocation of ecological services, largely falling into the public domain.

The application of the conventional approaches to economic valuation becomes further constrained when sustainability and social equity are also included as goals along with economic efficiency for ecosystem management (Costanza and Folke, 1997). While the methodologies for deriving values with economic efficiency is comparatively well developed, integrating equity and sustainability requires a better understanding of functional relationships between various parameters and phenomenon responsible for provisioning of the services in the first place and the social processes governing the mechanism of value formation (discourse-based valuation being one such approach).

As discussed earlier, most of the ecosystem services are biodiversity supported. A representative list of services is given below:

Table 4: List of ecosystem services (based upon Ehrlich and Ehrlich, 1981; Costanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment, 2003)

Category	Definition	Examples of goods and services provided
Production services	Production services reflect goods and services produced in the ecosystem.	Provision of: –Food –Fodder (including grass from pastures) – Fuel (including wood and dung) –Timber, fibers and other raw materials –Biochemical and medicinal resources –Genetic resources –Ornamentals
Regulation services	Regulation services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes.	–Carbon sequestration –Climate regulation through regulation of albedo, temperature and rainfall patterns –Regulation of the timing and volume of river and ground water flows –Protection against floods by coastal or riparian systems – Regulation of erosion and sedimentation – Regulation of species reproduction (nursery function) –Breakdown of excess nutrients and pollution – Pollination –Regulation of pests and pathogens –Protection against storms –Protection against noise and dust –Biological nitrogen fixation (BNF)
Cultural services	Cultural services relate to the benefits people obtain from ecosystems through recreation, cognitive development, relaxation, and spiritual reflection.	–Nature and biodiversity (provision of a habitat for wild plant and animal species) –Provision of cultural, historical and religious heritage (e.g., a historical landscape or a sacred forests) –Provision of scientific and educational information –Provision of opportunities for recreation and tourism –Provision of attractive landscape features enhancing housing and living conditions (amenity service) –Provision of other information (e.g., cultural or artistic inspiration)

These services can be observed to be flowing at different spatial scales, ranging from micro watershed to biome level. The variation in scale at which these services and subsequent benefits are arising could pose a problem in accounting and valuation. The ecological scale usually does not match the scales of decision making unit in accounting and valuation is executed. This mismatch, along with other epistemological gap, remains a challenge to scientists (Reid et al..2006). Provisioning services and cultural services are mostly related to tangible outputs so the producers or consumers are known and hence the scale is clearly identified, but regulating services occur at different spatial scale as shown in Table 5.

Table 5: Most relevant ecological scales for the regulation services—note that some services may be relevant at more than one scale

Ecological scale	Dimensions (km2)	Regulation services
Global	N1,000,000	Carbon sequestration
		Climate regulation through regulation of albedo, temperature and rainfall patterns
Biome–landscape	10,000–1000,000	Regulation of the timing and volume of river and ground water flows
		Protection against floods by coastal or riparian ecosystems
		Regulation of erosion and sedimentation
		Regulation of species reproduction (nursery service)
Ecosystem	1–10,000	Breakdown of excess nutrients and pollution
		Pollination (for most plants)
		Regulation of pests and pathogens
		Protection against storms
Plot–plant	b1	Protection against noise and dust
		Control of run-off
		Biological nitrogen fixation (BNF)

(Source: Hein et al. 2006)

This mismatch of scale and actors basically means that the gainers and losers have provided with an additional rationale for accounting of costs of restoration of biodiversity and management of ecosystem services, by internalising the conventional 'externality'.

2.4. *Biodiversity and international trade: Hidden costs in imports; Additional maintenance and restoration costs necessary for maintaining biodiversity in origin countries*

Trade is a major driver of change in ecosystem services and biodiversity. This macroeconomic driver causes the loss in one part of the world while the real action (import and consumption) happen elsewhere. Deforestation in Amazonia due to cattle ranching, for example, is stimulated by demand for Brazilian Beef in North America and Europe. Trading in virtual water especially from semi arid parts of the world, and loss of mangrove forest in Sundarbans due to the growing demand for tiger prawn from Japan and America are some further well known examples. While the foreign exchange earned in the national economies of India or Bangladesh reflect in its net income from abroad, the costs of biodiversity loss or coastal water pollution are not recorded, so violating the accounting principles of double entry book keeping. The importance of developing such accounts for looking at biodiversity loss issues can be illustrated by reference to the case of aquaculture.

Chopra, Kapuria and Kumar (2008, forthcoming) have documented the impact of aquaculture export from Sundarban mangroves and its impact on human well being, paying particular attention to the costs of biodiversity loss in the region. Modern forms of aquaculture undertaken in intensive and semi intensive ways with high stocking density is known to have profound impacts on coastal ecosystems. One of the major impacts happens to be the conversion of agricultural area and mangroves land for farmland devoted to aquaculture. Usually there is conversion of agricultural field and land adjoining the mangroves. Mangroves are ecologically fragile. One of the serious lacunas of modern aquaculture is that it is driven by current revenue maximization and hardly pays any attention to long-term ecological balance (Folke et al, 1998, Gunawardena and Rowan, 2005). Internalizing these ecological costs into the pricing structure would be a possible policy response. Accounting for the costs would be an absolute necessity. Internalization of these ecological costs into mainstream national accounts would reveal the costs society (the consumers in the industrial countries) should pay for its consumption and preferences and which are presently transferred de facto to the suppliers (invariably poor people in the aquaculture exporting country). Ecological costs if embedded into the pricing, would also pave the path for sustainable development.

Activities like aquaculture have serious ecological implications which impact society and the human well-being. By impacting on the state of ecosystem aquaculture impairs the functionality of ecosystems and their capacity to deliver a wide range of other services that would have a have beneficial value for the society. Modern aquaculture seems to emerge as one such activity especially in coastal areas and vicinity of mangroves. This can be better understood with the help of the concept of ecological footprint. Rees and Wackernagel (1994) explain ecological footprint as the land area necessary to sustain current levels of resource consumption and waste discharge by a human population. They were the first to introduce this concept but the spirit of the concept goes back to Bogstrom's 'ghost acreage' reflecting areas of agricultural land required for fuel consumption and Odum's (1989) 'energy' showing the amount of energy consumed per unit of area per year.

Using these ideas, Rees and Wackernagel estimated, for example that the Fraser Valley, Vancouver depends on an area 19 times larger that contained within its boundaries, for food, forestry products, carbon dioxide assimilation and energy. They go further and suggest that it would not be possible to sustain the present human population of more than 6 billion people at the same material standard that of the US without having at least resources of two additional planets (Rees and Wackenagel, 1996). In this context, sometimes, another concept-'carrying capacity' is also used and it is defined as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely without progressively impairing the functional integrity and productivity of ecosystems.

Some commentators maintain ecological footprint is a static concept. Ecosystems are dynamic and are characterized by a complex nature with presence of nonlinearity, thresholds and discontinuity (Costanza et al, 1993). Although the idea of an ecological footprint may not be able to capture the dynamic aspects of ecosystems and the ever changing equilibria, it does shed some light on the precise requirement of human activity like modern aquaculture. Ever expanding aquaculture is projected as saviour of growth and prosperity in developing countries but monoculture dominated aquaculture uses ecosystems services for the purposes of the culturing. It uses ecosystem for all its inputs requirements – feed, seed, water, waste treatment etc.

Folke et al (1998) have estimated the ecological footprint of seafood production. For shrimp pond farming, the requirement is 34-187 hectares per hectares of the farming area. Waste assimilation also needs 2-22 ha /ha of farming. Folke et al (1998) go on to suggest that that the implication of the size of the supporting mangrove nursery area becomes clearer when shrimp farming is analyzed at a national and regional level where usually the mangrove nursery area for post larvae extends far beyond the physical location of the shrimp farms.

Table 6: The Ecological Footprint of Seafood Production
(Values are area of footprint per area of activity, ha/ha)

Activity	Resource Production Support	Waste Assimilation Support
Salmon cage-farming, Sweden	40,000-50,000	…….
Tilpia cage farming, Zimbabwe	10,000	115-275
Fish tank system, Chile	…….	16-180
Shrimp pond farming, Columbia	**34-187**	……
Shrimp pond farming Asia	……	**2-22**
Mussel rearing, Sweden	20	…..
Cities in the Baltic Sea Drainage basin	133	…..

(Source: adapted from Folke et al, 1998)

Thus, the numbers are contrary to the idea of sustainable practise of aquaculture farming. In Sundarbans, for example, the way the prawn seeds are collected by the locals causes serious damage to the wild fish and other coastal organisms. Aquaculture in the region remains largely dependent upon wild caught seed. This will have serious consequence for coastal biodiversity.

Shrimp along with salmon, constitutes the major share in aquaculture in terms of value and volume of global trade. Aquaculture as a whole has experienced an added momentum in production and trade all over the world in last three decades (1975-2005). The growth has primarily been in the developing countries during from around 1985. Aquaculture is farming of aquatic organisms like fish, shrimps, crustaceans, and many other species for food and ornamental purposes (e.g. pearl). The most distinctive feature of aquaculture is its controlled production with greater precision in inputs. The FAO defines aquaculture as "the farming of aquatic organisms in inland and coastal areas involving interactions in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated". The International Standard Industrial Classification of All Economic Activities recognizes aquaculture as separate activity. Although for recent years only the data on aquaculture is provided separately from the data on fisheries.

Traditionally farmers in tropical climates located near the fresh and marine waters have been growing shrimp and other species for subsistence consumption. Since 1980's the production has picked up and trade has accelerated. The average rate of growth of aquaculture has been more than 10% per annum since 1980's it reached 259.4 million tones with the values of 70.3 billion in 2004.

Table 7: Volume and Value of Aquaculture Production at a Glance

	Quantity		Value		
Country	**M tonnes**	**%**	**$ million**	**%**	**$'000 / tonne**
China	30.6	67.3	30.870	48.7	1.01
India	2.5	5.4	2,936	4.6	1.19
Vietnam	1.2	2.6	2,444	3.9	2.04
Thailand	1.2	2.6	1,587	2.5	1.35
Indonesia	1.0	2.3	1,993	3.1	1.91
Bangladesh	0.9	2.0	1,363	2.2	1.49
Japan	0.8	1.7	3,205	5.1	4.13
Chile	0.7	1.5	2,801	4.4	4.15
Norway	0.6	1.4	1,688	2.	2.65
USA	0.6	1.3	907	1.4	1.50

Source: The World Bank, 2006.

It is also noteworthy that capture fisheries have grown at the rate of only 2% per annum for the same period. Although the aquaculture has obtained the status of global industry, the share for developing countries is more than 90%. Out of this Asian countries contribute 89% of aquatic production (80% in value terms) (WB, 2006). China has the major share at 67% and 49% in volume and value terms respectively among Asian nations, followed by India. Following the principle of accounting and the spirit of sustainable development, the costs of biodiversity loss due to this export must be accounted and adjusted but the national accounts in consuming countries does not seem to be doing that.

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Chapter 3. Framework of ecosystem accounting

The EEA is developing ecosystem accounts in the context of the experimentation and implementation in Europe of the UN System of integrated Economic Environmental Accounting (SEEA2003[11]). As a first step, land cover accounts (LEAC) have been produced for 1990 and 2000 (24 countries) [12] and will be updated for 2006 (35 countries). Ecosystem accounts are currently tested for wetlands, grassland, forests (with IUCN) and rivers. The framework of ecosystem accounting will be submitted to CBD in the context of the Potsdam G8+5 initiative of 2007 of valuing the cost of inaction regarding biodiversity. For Eureca!2012, the new MA for Europe, ecosystem accounts are an important way of answering crucial policy questions related to human well-being, sustainability of the use of natural capital, adaptability to climate change, conflicts between sector policies or environmental debts resulting from international trade. These points were presented in the EEA contribution to the "Beyond the GDP" conference (Brussels 19-20 November 2007). In parallel, ecosystem accounts are discussed within the UN London Group on economic-environmental accounting in the perspective of the revision of the SEEA2003 and the drafting of a special chapter and handbook.

Purpose of ecosystem accounting

Ecosystem accounting is an attempt to answer three basic questions related to economy-nature relation:

is the renewable ecosystem natural capital maintained over time at the amount and quality expected by the society?
is the full cost of maintaining the natural capital covered by the current price of goods and services?
is the total of goods and services supplied to final uses either by the market (and government institutions) or for free by the ecosystems, developing over time?

Natural capital: this first issue requests at least 3 answers related to:

- the amount and quality of ecosystem assets: it is measured by natural capital accounts in physical units;
- the amount and quality of ecosystem assets expected by the society, which depends on willingness by the various social groups to keep ecosystem services for productive and non productive purpose, to keep as well existence values not translatable into services and to the budgetary constraints that the society is ready to face. This willingness is expressed in targets stated by international or regional conventions, regulations or directives and national laws. These targets can be translated into the accounting framework.
- the gap between actual natural capital and the society objectives, which is the difference between (b) and (a).

The additional cost of maintaining the natural capital is obtained by pricing the amount of work (or the abstention of use) necessary for filling the gap measured from physical accounts. It comes in addition to actual management and protection expenditures. As long as the restoration of a given ecosystem is generally necessary for maintaining the whole ecological infrastructure, restoration costs are included. The additional maintenance cost has to be computed for domestic ecosystems as well as for imports. The additional maintenance cost can be added to the

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[11] UN, EC, IMF, WB, OECD, Integrated Environmental and Economic Accounting (SEEA2003), *UN Statistical Division, New York, 2003.* *http://unstats.un.org/UNSD/envAccounting/seea2003.pdf*

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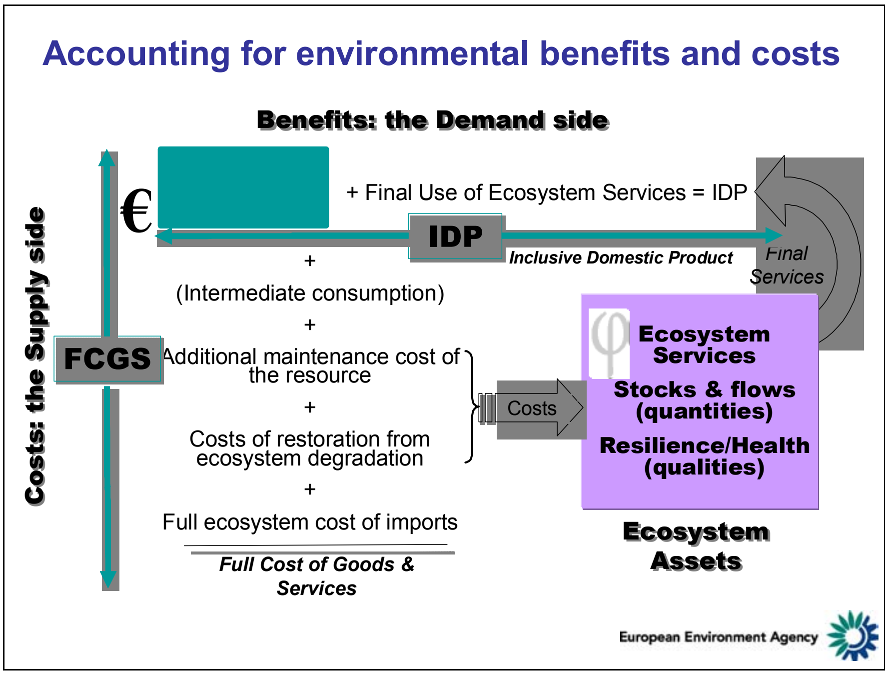
respective products, for computing a full cost of goods and services to compare to production output; this is a strong sustainability indicator. It makes sense as an aggregate, by sectors, by companies or by products.

The ecosystem services contribute to a large part to the value of goods and services or are enjoyed individually or collectively by end-users as free non-market services. The market value of marketed ES is entangled into prices. If, because of unaccounted externalities, market prices are undervalued, an adjustment will result in terms of "full cost of goods and services". From a demand perspective, market prices are taken as such. In addition to market, some ecosystem services are enjoyed for free: recreation services, regulation of climate or water regime… They have to be added to the conventional GDP for measuring an Inclusive Domestic Product. This aggregate will tell, for example that the increase of GDP is balanced by a decrease of the free ecosystem services resulting either from their commercialisation of from environmental degradation. Accordingly, the inclusive domestic product would not grow as fast as GDP and even decrease in some case. The free end use non market ecosystem services have to be measured in physical units first, from land use and people actually using it. Valuation comes in a second step, in reference to the willingness to pay for these services.



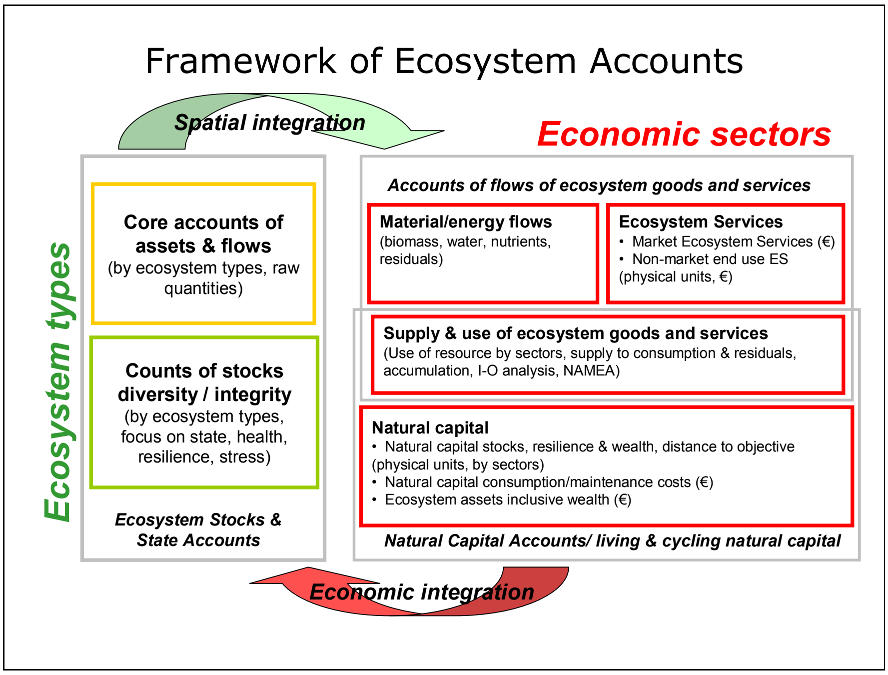
Framework of ecosystem accounts[13]

It can be summarized as such:

Accounts established by ecosystem types (stocks, flows, resilience, services, stress) on the one hand and by sectors on the other hand (material energy flows and ecosystem services by origin, supply & use, natural capital) on the other hand.
Ecosystem services in money (when imbedded in products) or in physical units and then in money (free end use services)
Maintenance and restoration costs of ecosystems (up to society stated objectives) in physical units and then in money.

13 Weber, J.-L., *Implementation of land and ecosystem accounts at the European Environment Agency*, Ecological Economics, Volume 61, Issue 4, 15 March 2007, Pages 695-707

Natural capital (ecosystems) in physical units only in the “dual integration” perspective.
Inclusive wealth calculation as the ultimate step but not a pre-requisite to the implementation of the other accounts.
Integration of geographical information (land cover, rivers, thematic information, zonings) with socio-economic statistics.



Stocks

The main types of stocks of ecosystems are:

- Land cover: land cover is the synthetic image of ecosystems and land use. This property makes land cover a key information infrastructure for ecosystem accounting. The European Environment Agency has produced land cover accounts (LEAC) 1990-2000 for 24 countries from its Corine inventory; a 2006 update is going on for circa 35 countries. The EEA looks forward to a Pan-European and Mediterranean extension of LEAC, with GlobCover2005 and other sources.
- Rivers: the principles of classification of river ecosystems in SEEA2003/ water accounts and SEEAW. The elementary units of rivers or river reaches are analogous to land cover units and the two databases can be easily combined. River units (ecosystems) are measured in standard-river-km (where 1 srkm = 1 km * 1 m^3/second). They are classified according to their size and their hierarchical position in the river basin.
- Coastal systems and sea units are more difficult to define due to their fluid and dynamic nature. Coastal ecosystem can be mapped however (existing projects in several EU countries). In the sea, particular stocks, resilience, flows, functions, and services can be addressed by ecosystem accounts. They are of course fishes and other wildlife, fish farms, algae and sea grass beds, coral reefs. Erosion and accretion of the coastline is also part of the subject.
- Soil is at the same time a vital asset in the present time as in the long run and an extremely heterogeneous ecosystem. Therefore, stock accounting will be framed restrictively from the point of view of soils functions and resilience. Main functions are support to vegetation, water buffering and storage and carbon sequestration.
- Atmosphere: there is no stock account of the atmosphere presently foreseen although some elements could be accounted as CO_2 and other pollutants concentration or (un)stability

regarding climate events. Instead, the maintenance cost of services of climate regulation can be calculated in reference to international agreements.

Flows:

Beyond C/ CO_2 exchanges of terrestrial and sea ecosystems with the atmosphere, basic flows are of water, biomass, N, P, species and land cover. Land doesn't generally flows, but he cover of land yes, when a given type is consumed for producing (formation) a new one[14].

Health and "quantityquality" measurement

One of the aims of integrated accounting for ecosystems and services is to come to a holistic approach of quantity and quality aspects. This is in no way an academic position but a very practical one instead. Which water agency would not care of the quality of the water abstracted, distributed and returned? Is maintaining a stock of timber a sustainable policy as such when most of all other forest services[15] are sterilised by the plantation management and the resilience of the new system very problematic? Is it possible to account for the sustainable use of fish stocks of particular commercial value without accounting for the whole food chain and anticipate possible "flips" in populations' dynamics?

The stocks of ecosystems and associated flows (which measure their functioning or their "production function") are therefore measured in quantities with quality attributes. These attributes are observed according to the "ecosystem distress syndrome" approach based on the observation of symptoms. One important point is that the EDS methodology can be implemented at any scale, from the complete micro modelling of ecosystems in case studies up to particular ecosystem types and up to the macro level. Other macro EDS indicators currently foreseen for ecosystem accounting in Europe are one indicator based on the specialism degree of species communities and the Human Appropriation of Net Primary Production (HANPP).

Classification of ecosystem services

Ecosystem services are outcomes of ecosystem functions but are just a subset of them, what is used by the people. The distinction between internal ecosystem functions and ecosystem services is essential both for avoiding double counting and framing the scope of the activities. The ecological functions in general are assessed in the asset account as stocks, flows and quality counts.

The ecosystem services are classified in reference to MA, the Millennium Ecosystem Assessment, with some adjustments which are currently discussed for MA2.

An updated classification of ES, matching requirements of both MA and SEEA2003 has still to be elaborated in full and validated. However, a consensus exists on the principles of its elaboration – according, for example to the scheme below – if not on every detail yet.

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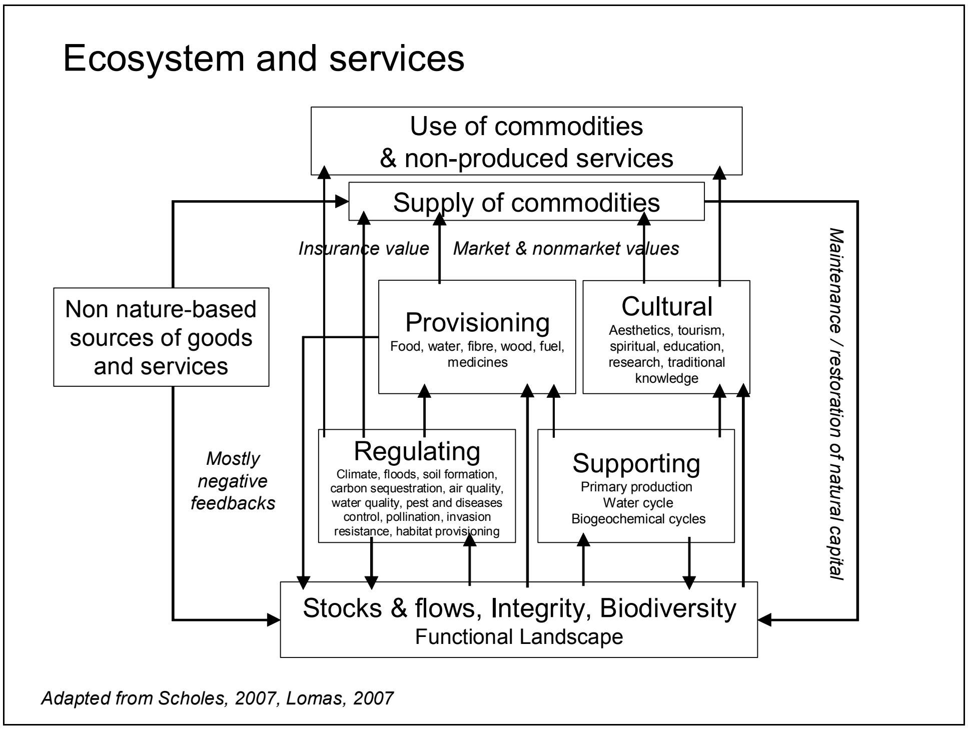
[14] See "Land accounts for Europe", op. cit.

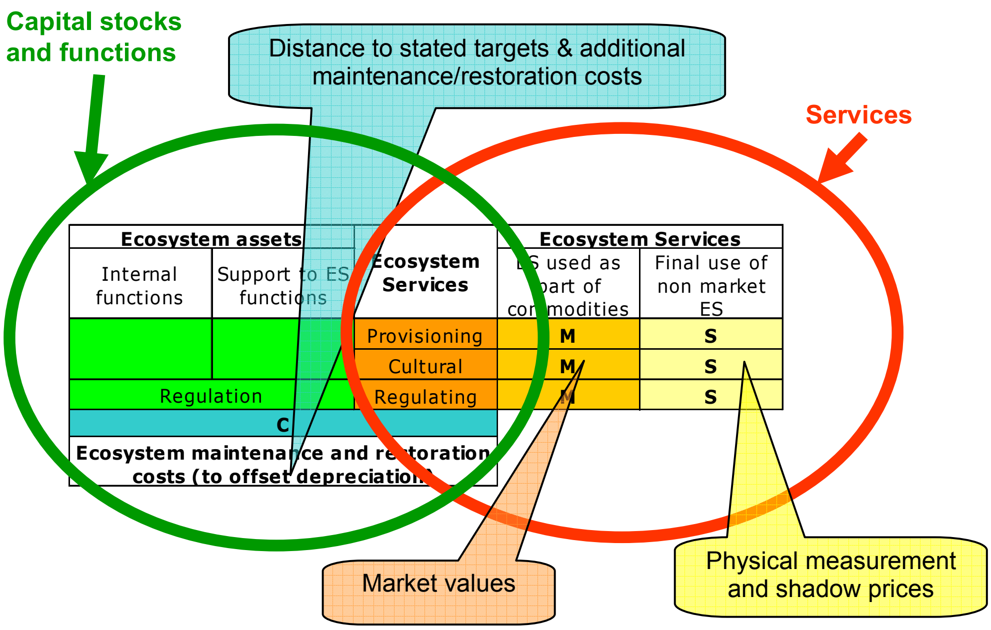
[15] In the "green" accounts of Indian States, these services are shown to have a monetary value of the same magnitude as that of timber. Reports can be downloaded from http://www.gistindia.org/index.asp



In the biodiversity assessment, ecosystem services are further analysed according to the short term or longer term dependency from biodiversity. The issue is addressed in Chapter 3 Biodiversity focus and Chapter 5 Case studies.

Measurement and valuation of ecosystem services

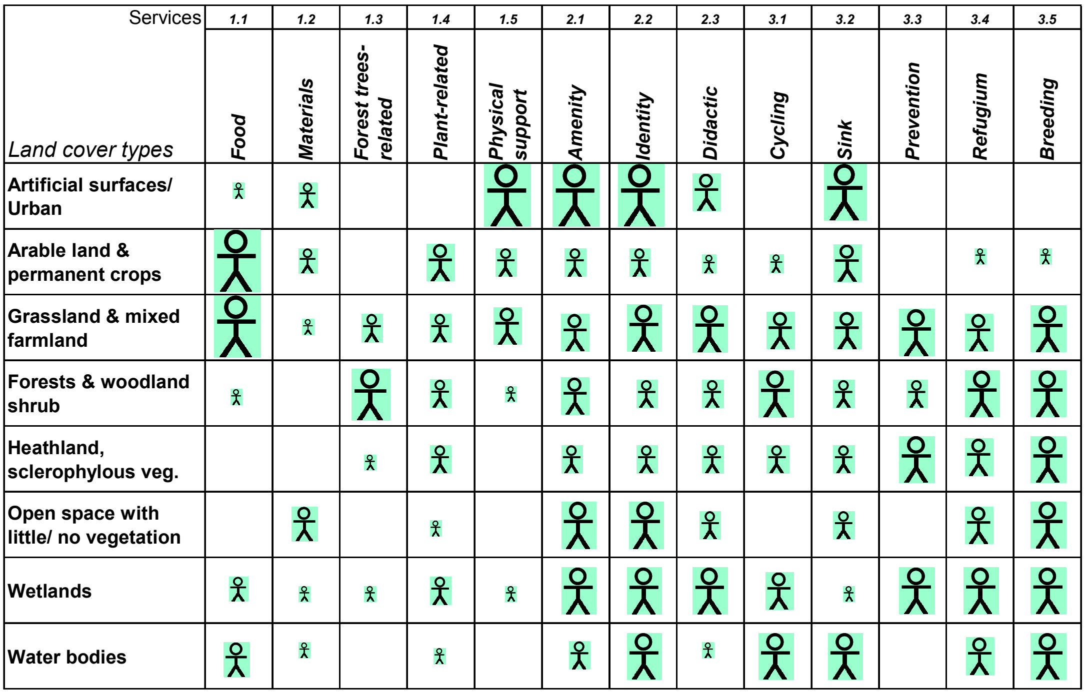
Distinctions have to be made between market and non-market ES.



Only final use non-market ecosystem services need to be measured and valued. The services entangled in the market goods and services are considered as being part of their price – whatever the price. Market prices (and GDP accordingly) are taken as observed.

One important point is that the same service (e.g. enjoying sea-side scenery) can be either marketed or not, according to the existence of an actual payment or imputed payment (housing rents) or not. Regulation services provided by ecosystems when used as collective goods have to be considered as natural capital input to add to current market values. A systematic measurement and valuation of the “free end-use” recreational and regulating ecosystem services will probably lead to substantial amounts.

In any cases, the final use non-market ecosystem services are first measured in physical units considering land use types in particular places, people and time allocations. These services are valued in a second time according to the most credible methods of shadow pricing; it may vary from case to case. Important research and large number of case studies have been carried out these last year. Therefore, the issue is not so much to invent new valuation methods but to screen and assess existing ones according to their specific purpose, and then to address the difficult question of the “benefit transfers”.



Measurement and valuation of maintenance and restoration costs

Part of the maintenance costs of ecosystems is paid by economic agents as management and environmental protection expenditures. Additional costs would be necessary to cover in some cases to keep the ecosystems at the level desired by the society. These costs can relate to works for repairing the ecosystem (or compensating degradations) or to loss of profit resulting from avoidance of use. In both cases, physical measurements are the basis of cost calculations.

Measurement and valuation of full ecosystem maintenance and restoration costs is crucial, for public policies a well as for the companies. Public policies are generally designed and implemented by broad sectors – the competencies of ministries. Efforts for integrating environmental concerns in sector policies in Europe have shown obvious limitations resulting from unwanted consequences of one sector action to another sector. A similar situation is faced by companies which are in a position of establishing a detailed balance of their direct environmental costs but are missing information for their indirect costs – in short their costs on the global ecosystem. Therefore, accounting for and valuing the additional (or hidden) ecosystem maintenance and restoration costs is essential.

The reference to stated society objectives makes ecosystem accounts a good candidate for scenario development (e.g. additional costs for maintaining climate regulation atmosphere ecosystem services can be computed in reference to Kyoto, post-Kyoto or an objective of carbon neutral economy).

Conclusive (provisional) remarks: Ecosystem accounts, biodiversity benefits, public decision making and International Payments for Ecosystem Services

Accounts are helpful for aggregating and comparing data, physical and monetary. They help avoiding double-counting. Based on information that they combine and aggregate, ecosystem accounts aim at making the best use of data collected elsewhere for other purposes. However, they can support judgments on the quality of this information in terms of consistency (and therefore its informative capacity for trade offs), completeness and spatial distribution.

A few recommendations can be usefully derived from the accounts:
Ecosystems as well as ecosystem services are space specific; spatial analysis matters.
Ecosystem stocks and resilience should be measured first in physical units and then values, where possible.

The most relevant valuation of ecosystem stocks and resilience (the living/cycling natural capital) is that of their maintenance and/or restoration cost. They can be split between effective expenditure of environmental protection and maintenance and additional costs required for maintaining ecosystems at an appropriate level.

In a national perspective, this additional cost is an allowance for depreciation currently recorded in no accounting book. It measures the amount which should be reinvested in nature in a future period as long as the full price of the products has not been paid in the current period. It is a liability or debt which will have to be compensated by futures generations in the country. If not the total, this is an element of ecosystem service price justified by national sustainability requirements.

Considering international trade, an additional cost of ecosystem maintenance and restoration maybe included. The importing country has to add-up this component into the full cost of the products it uses. In this case, the importing country subscribes a “virtual” debt to the exporting country where ecosystems are degraded. This is another element of ecosystem service price justified by global sustainability requirements. Note that it doesn’t cover the total rent from ecosystem assets.

The value of ecosystem services entangled in market commodities (and possibly government services) is not isolated at this stage. This value can be very low if the companies don’t internalise their costs. The full price of ES would include in that case the additional cost as described previously plus a rent component which is not deducible from the accounts.
The value of non-market end-use individual or collective ES is computed according to various techniques of expression of the willingness to pay. This willingness is that of the people who actually use these services. It might be lower than the full maintenance cost which addresses to-day’s as well as to-morrow’s benefits. .

Chapter 3. The broad picture of Pan-Mediterranean wetlands

3.1. Wetlands as Socio-Ecological Systems

3.1.1. What is a Social-Ecological system?

Gallopin (1991) defined social-ecological system as a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction. Both social and ecological systems contain structures that interact interdependently and each may contain interactive subsystems as well (Vandewalle et al., 2008). The social components may be the individuals, organized groups, or societies at large. Institutions guide interactions with the ecosystem, and determine how humans manipulate ecological systems to receive goods and services for their benefit (Fig. 1).

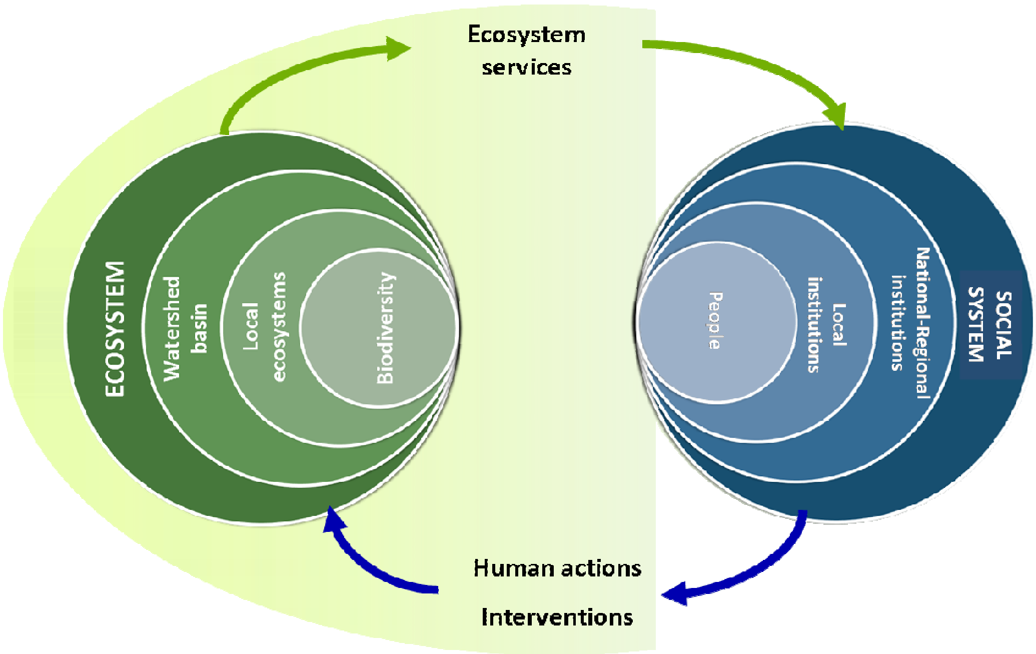


Figure 3.1. Conceptual diagram of elements of a social-ecological system.

Social systems comprised of individuals, groups, networks and institutions (rules, regulations and procedures) intervene to obtain services from ecosystems. Social system develops individual actions (fishing, hunting, agriculture, etc.) as well as local or global interventions (development projects, or conservation and restoration projects), which modify ecosystems. (Modified from Resilience Alliance, 2007).

The scale issue is at the core of the SES analysis. As shown in Fig. 1, social and ecological systems function and interaction at different nested spatial and temporal scales. Regarding spatial scales, for example, aquatic species are a part of a local wetland, which also is part of a larger watershed basin. Similarly institutions may be considered hierarchically, as nested set of systems from local level (local organizations or local rules), national (national organizations and national laws), to the international (Ostrom, 1990). Regarding time scale, there are historical records about how ecosystems and human societies are interlinked across present and future.

SES are thus complex multi-scale systems, in which each scale can be characterised by components and processes with time rates related to specific orders of magnitude, spanning from fast localised processes to large processes occurring at larger scales (Holling et al., 2002). For instance, ecosystem services such as food production are dependent on the growth of annual plants and the panning of agricultural seasons, but also on biogeochemical processes and social driving forces occurring at rates of decades or centuries. Sound analysis of SES needs also to take into account processes stemming from cross-scale interactions.

3.1.2. Why is important to account for SES?

With the Age of the Enlightenment the separation of nature and society became a foundational principle of Western thought (Davidson-Hunt and Berkes, 2003). Nevertheless, human influence in nature has increased in such an extent since the industrial revolution that today many ecosystems con not be understood if social dynamics are not taken into account. The omnipresence of human impact in nature lead Paul Krutzen (FECHA) to coin the notion of the *anthropogene*, in reference to the present era, in which human impact has displaced geological processes as the main driving forces in our planet.

As a consequence, the human-nature dichotomy has proved to be inadequate for analysing sustainability problems, characterised by phenomena that usually occur at the interface between nature and society. The SES concept emphasizes the 'humans-in-nature' approach (Berkes and Folke 1998). It aims to analyse social and ecological dynamics that can not be successfully captured from the human-nature dichotomy, such as those related to ecosystem services and their management.

There is an increasing amount of studies on the relationships between ecosystem and social systems, aiming to identify and characterise interactions existing between people, biodiversity and ecosystems (Anderies at al., 2004, Liu et al., 2007). However the social-ecological system perspective has been rarely used in studies for the Mediterranean basin.

This seems to be a paradox, since Mediterranean landscapes provide an excellent study area for applying the SES concept due to their historical background. Resource use and transformation is so ancient in this region that Naveh and Lieberman (1993) suggested that there are no strictly natural landscapes in the Mediterranean Basin, arguing that it is more accurate to talk about cultural landscapes. In fact, it is known that Mediterranean landscapes reflect today more than eight millennia of an agricultural-forestry-pastoral way of life (Grove and Rackham, 2003; Butzer, 2005). Furthermore, the fact that biodiversity hotspots have been able to emerge within highly humanized landscapes providing diverse ecosystem services, witnesses a successful long term nature-society co-evolutionary process in the Mediterranean basin (Gómez-Baggethun et al., to be published).

For example, dealing with uncertainty related to droughts, floods and other disturbance entailed the need of searching for water reserves and the employment of techniques to extract, transfer and use the available local water. In fact, first settlements of Mediterranean culture were located close to the main river basins and the groundwater reserves (Llamas, 1989). The use of irrigation techniques was already usual 6 000 BP in Mesopotamia by the exploitation of rivers, and the use of annual floods (Bazza, 2006). The ancient Sumerian know-how about irrigation techniques were used and improved by Romans to supply great Roman urbs and termas. After that, Muslim civilization of Al-Andalus constructed Mediterranean xero-gardens like La Alhambra and complex systems of groundwater use by channels, cultivation terraces, etc. at the arroyos (Ramblas), and surface water use at the floodplains of streams and rivers (Vegas). Decentralized institutions like medieval Water Court (Valencia, E Spain) were created to avoid social problems in the distribution of water from channels.

Our objective here is to integrate SES into the wetlands accounting approach and to understand why this concept it is important for the biodiversity conservation within Mediterranean Wetlands.

3.1.3. SES characteristics

When combined within integrated models, social-ecological systems exhibit novel behaviours that would not be expected from isolated social and ecological systems. One of the most important attributes of SES is that both subsystems, ecosystem and social system, are interlinked and therefore, need to sustain each other through adaptive feedbacks (Gatzweiler and Hagedorn, 2002). SES exhibit non-linear dynamics with thresholds, feedback loops, time lags, resilience, heterogeneity, and surprises (Liu et al., 2007). Sound analysis of to capture these complex dynamics entails to describe not only social and ecological characteristics, but also others that emerge from coupled social-ecological dynamics:

- Social characteristics can be described by socio-economic indicators such as employment, age and gender distribution, main economic sectors, administrative boundaries, stakeholders, organisations, etc.

- Natural characteristics aims to describe ecosystem functioning and structure, which entails identifying ecosystem types, species, ecosystem functions and natural disturbance regime.

- Characteristics resulting from coupled social-ecological dynamics such as lad-use covers, ecosystem services, human-induced environmental impact, institutions and social-ecological resilience.

Methodology to define and characterize SES for Mediterranean wetlands

Although the SES concept is being increasingly used, there is a scarcity of literature addressing how to operationalise this concept, especially concerning how to characterise socio-ecological boundaries.

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3.2. Three scales, three pictures of the Mediterranean Wetlands

Accounts are established for Mediterranean Wetlands socio-ecological systems (SES) at different geographical scales: the macro, meso and micro. When the analytical concept of SES is the same at any scales, its implementation may differ according to data availability and needs for comparisons. Three scales and three methodologies for mapping SES are used in the Mediterranean wetland accounts case study.

3.2.1. **The Pan-Mediterranean map** (including Atlantic and Black Sea neighbourhoods) frames the broad question as specific macro-assessments and aggregates relevant to that scale. An example of specific macro assessment is that of wetlands and bird flu.

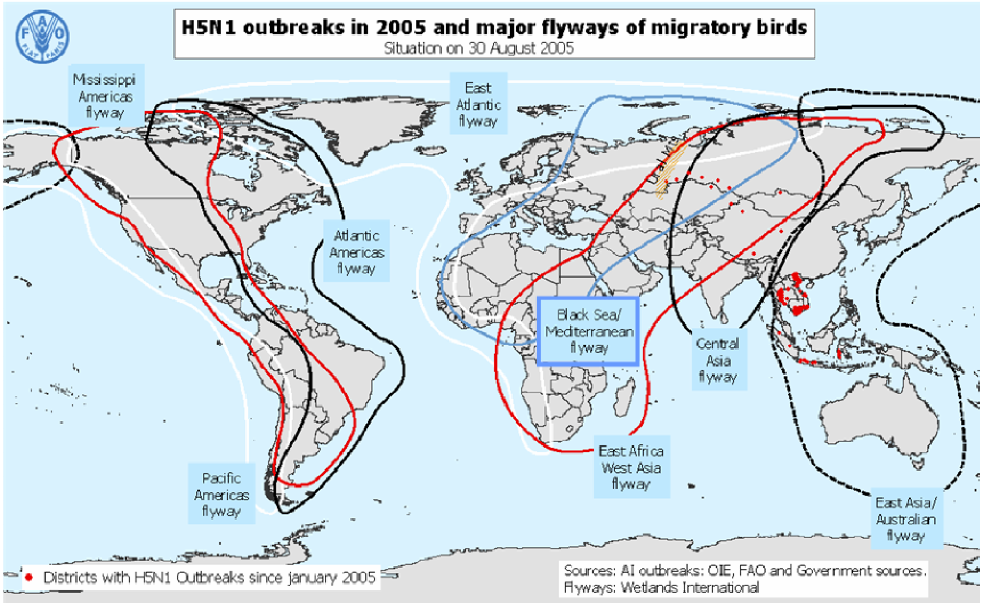
Wetlands and Bird Flu Prevention

"Wetland depletion has direct implications for migrating wild birds. Wetland habitat worldwide continues to decline, primarily due to agricultural expansion and urban development, resulting in fewer staging areas for migrating birds. In these situations, remaining wet areas associated with rice paddies and farm ponds would be expected to be increasingly attractive to wild birds that lack sufficient natural habitat during staging, nesting and migration activities."

David J. Rapport et al. Avian Influenza and the Environment: An Ecohealth Perspective, report to UNEP/DEWA, 2006 http://www.unep.org/dewa/products/publications/2006/

In *"Bird Migration Routes and Risk for Pathogen Dispersion into Western Mediterranean Wetlands"* (Jourdain E. et al. Emerging Infectious Diseases Journal Volume 13, Number 3–March 2007 - http://www.cdc.gov/eid/content/13/3/365.htm). A correlated effect is highlighted: the concentration of migratory birds in the remaining wetlands increases the risks of cross contamination. Bird Flu and Nile Virus are given as examples of serious threats. Threats to human and ecosystem health in this case cannot be disentangled.

As explained by Rapport, wetlands supply a "regulation" ecosystem service essential for limiting present and future risk of birdflu pandemic. This service can be measured and valued according to insurance practices, taking into account population exposed, risk factors and unitary costs of treatment. The availability of this service in due course depends on the appropriate amount of healthy wetlands maintained and restored. Necessary additional costs for this maintenance and restoration can be computed accordingly and accounted as allowances for depreciation which should be imputed to the opportunity cost of other wetland areas use. The map below produced by Wetlands International and FAO, shows up that Mediterranean and Black Sea are at the core of a main global flyway for migratory birds.



The global character of the bird flu problem requires a direct approach at the macro scale, the so-called Black Sea/Mediterranean flyway being the relevant context in that case. Accounts will balance maintenance and restoration costs with the foreseen risks – and costs – of pandemic.

Other issues are common to the sea basin. They are in particular the population migratory flows described as "*littoralisation*" by UNEP/Blue Plan. The process is driven in particular by tourism in summer period concentrated towards areas of interest; more than 30% of world tourism is attracted by the Mediterranean region, 80% of which by the European countries (Spain, Southern Italy and France, Greece). The Blue Plan foresees for 2025 an average of 200/250 millions visitors per year. Tourism creates seasonal (when tourists come) as well as permanent stress (buildings, infrastructures and the people taking care of them in the low season). This is a threat for the quality of the natural landscapes (to which wetlands contribute) which attract tourists to-day.

Another example directly linked to wetlands services is food provision, in particular fish and shellfish.

Mediterranean Wetlands and Proteins

"On the north African coast fish and shellfish are an important source of protein for many people. In some parts of the Mediterranean, fishing for own consumption and for sale at local markets and restaurants is still a common practice.

Mullet, sea bream, sea bass and eel are all flagship fish species of Mediterranean wetlands. Mullet larvae need the sheltered areas of coastal lagoons, where they feed on weed, invertebrates and rich sediments *found on the bottom of the lagoon, to grow into adults. It might take a young mullet as long as three years until it leaves the protected environment of the lagoon for the open sea.*

Domestic livestock are grazed on marshes that provide high quality grazing, even during the driest summer months. The Camargue delta, on the Mediterranean coast of France supports approximately 8.000 horses and cattle..."

Source: MedWet, the Mediterranean initiative of the Ramsar Convention

http://www.medwet.org/medwetnew/en/04.RESOURCE/04.1.wetlandfacts01.html

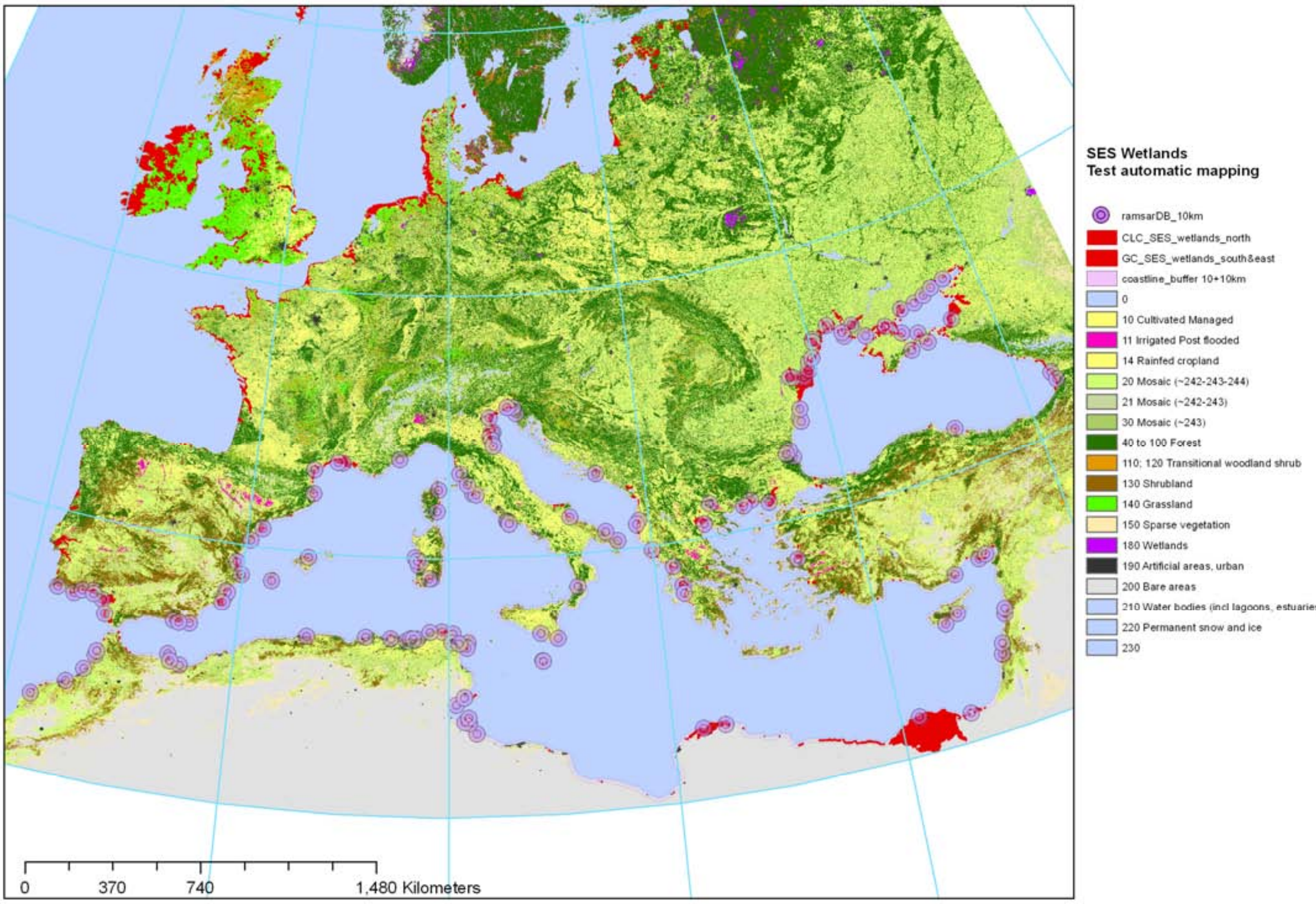
Coastal lagoons, estuaries and delta are productive systems for fish and shellfish, both for the needs of local people and commercial production. They are however fragile systems because of the nutriments concentration which makes them productive. In France, for example, the Bouzigues oysters from the lagoon of Thau are famous all over the country. From time to time in summer however, problems may happen in relation to water conditions under the name of "malaigue" ("sick water" in the occitan regional language) which results from the combination of climatic conditions (temperature, no wind) and high concentrations in nutriments and creates hypoxia, a loss in dissolved oxygen lethal for oysters, as well as other shellfish and fish which are one of the pillars of local economy. Since the 1980s, efforts have been done to purify waste water in particular from tourists, numerous in summer in the region but concerns remain and management of the water streams between the sea and the lagoon ecosystem is now considered. In Amvrakikos, Greece, a national park, a similar event. *"In the evening of 17 February 2008 [...] some 600 900 tons of fish on three fish farms in the area died of asphyxia within a short space of time (two hours) owing to lack of oxygen, which, according to the local Directorate of Fisheries, was caused by rising strata of anoxic water." (Source: written question by MEP Arnaoutakis to the Commission – 5 March 2008).* Pollution is as well an important cause of the drop in fish catches (in particular high value sturgeons) in the Danube delta. In several other places, the development of commercial farming of fish and the pollution that it generates has lead, or is currently leading to drawbacks, not only at local people's economy and nature conservation, but at the commercial activity itself.

Comprehensive accounts of the multiple services – not only the commercial ones – supplied by the wetlands will highlight the appropriate trade offs. A second assessment based on accounts of ecosystem integrity will allow accounting for the costs of preventing biodiversity loss.

A test map for framing ecosystem accounts

A first attempt of producing a map of wetland SES at the Pan-Mediterranean scale has been carried out with GlobCover2005 version-1 submitted for evaluation by ESA, the European Space Agency. This first test – necessary in the absence of an alternate map which could have been used – will be improved in July with GlobCover2005 v2 and repeated at the end of the year with another version adapted by the EEA to its own European Corine Land Cover (CLC) map on which the development of land and ecosystem accounts is currently based.

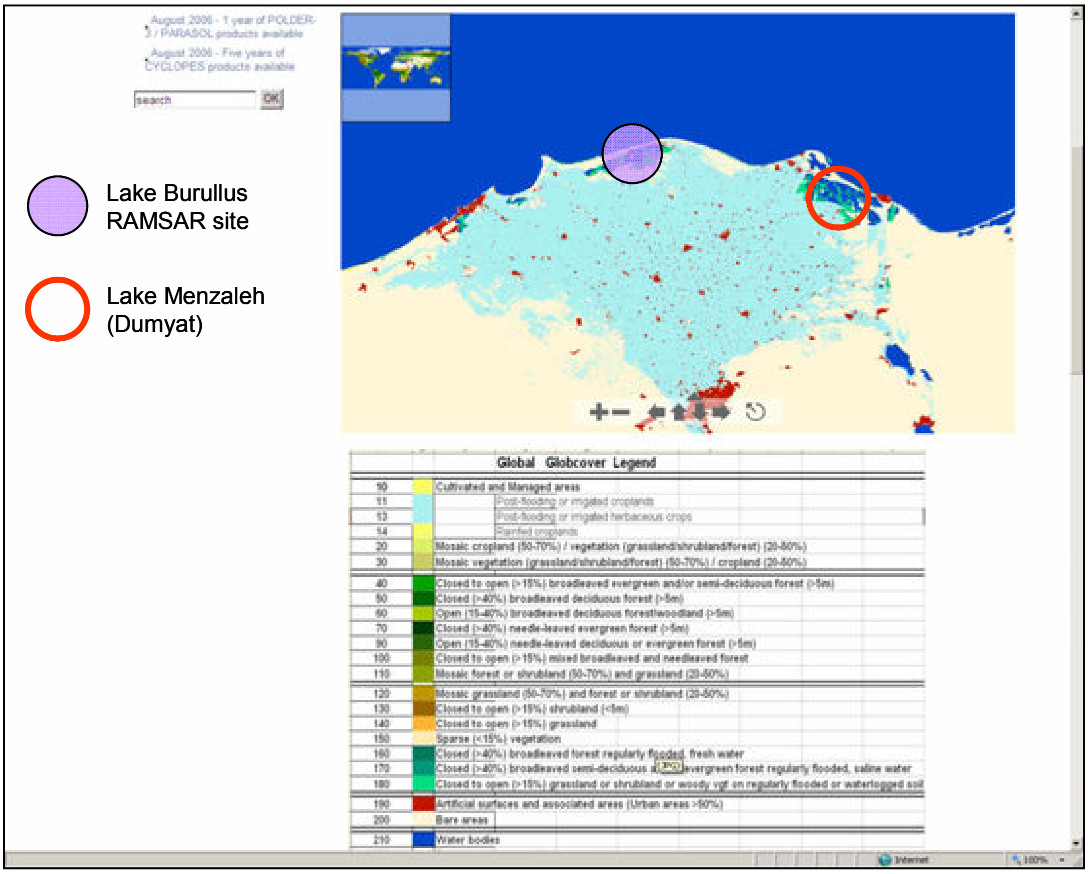
The first test map combines therefore 3 types of information: Ramsar sites in the 10 km coastal strip as mapped by Wetlands International (center of sites, no boundaries yet), SES (Ramsar and non-Ramsar, with boundaries) produced automatically for Europe's Mediterranean with CLC, and sites extracted from the first classification of GlobCover.



Sources: ESA/GlobCover2005, Wetlands International/Ramsar, EEA/CLC

Figure 3.2 Test map of SES wetlands for the Mediterranean and Black Sea.

An example of the information provided at medium scale by satellite imagery can be found on the website where Globcover products are disseminated:



Source: http://postel.mediasfrance.org/breve.php3?id_breve=21

Figure 3.3 Identification of coastal wetland socio-ecosystem in the Nile Delta, Egypt

Lake Menzaleh is not designated to the Ramsar Convention; Lake Burullus is, but its map is not available in the database. In both cases, medium resolution satellite imagery is a fast solution for setting the scene at the continental/ global scale, with a sufficient detail for starting monitoring and – in combination with other data, accounting for ecosystems.

Additional details can be supplied by high resolution satellites. This is the purpose of the GlobWetlands programme of the European Space Agency where high to very high resolution satellite images add-up to the mapping of wetlands. The frequency of satellite images acquisition allows monitoring seasonal dynamics, all the more as radar images get rid of clouds issues. Last, analysis of images gives important information of land and water biomass, eutrophication, turbidity/sediments, all kind of data very useful for ecosystem accounting.

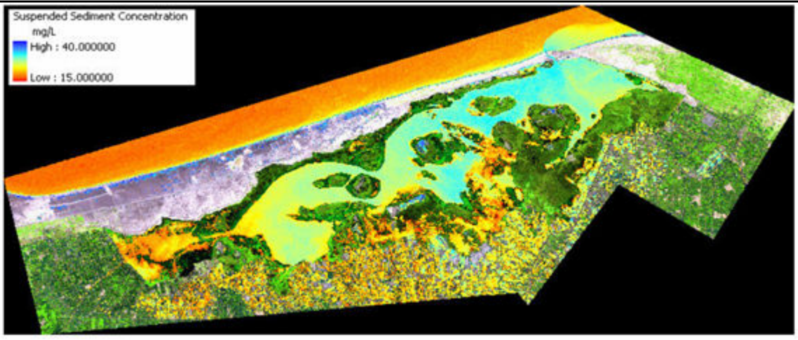


Figure 14 : Suspended Sediment Concentration over Lake Burullus, Egypt

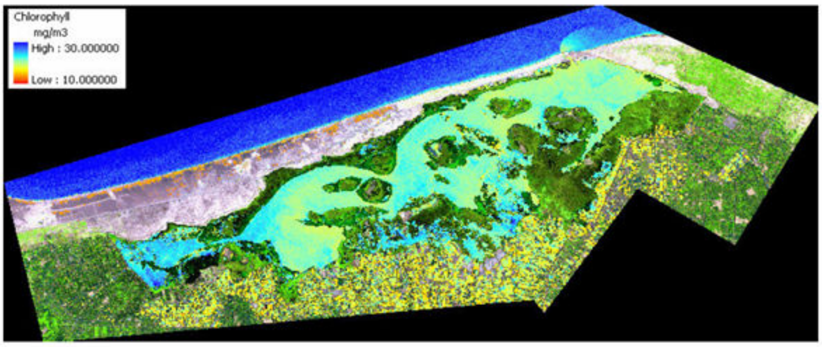


Figure 15 Chlorophyll content over Lake Burullus, Egypt

Source: Courtesy ESA/DUE/GlobWetlands

Figure 3.4 GlobWetlands: Lake Burullus, a Ramsar site, Egypt

3.2.2. Map of European Mediterranean SES wetlands with CORINE land cover

CORINE land cover is the name of the European map produced so far for 1990 (circa), 2000 and being updated for 2006 for more than 35 countries. Land accounts are implemented in Europe with CLC (EEA 2006) and accounts of terrestrial ecosystems are developed upon that pattern. Maps of stocks and change are gridded at 1 hectare and 1 km2. Therefore, CLC is the appropriate data infrastructure for accounting at the meso scale.

For being able to accounting for the whole set of socio-ecosystem wetlands of the European Mediterranean area in the absence of an individual map of each of them, an automatic mapping of each of them has been attempted. This mapping respects the main characteristics of SES and combines a core areas composed of wetlands as defined in the CLC nomenclature with associated areas which should be considered altogether (included village, irrigated area connected to wetlands, dunes separating wetlands from the sea...).

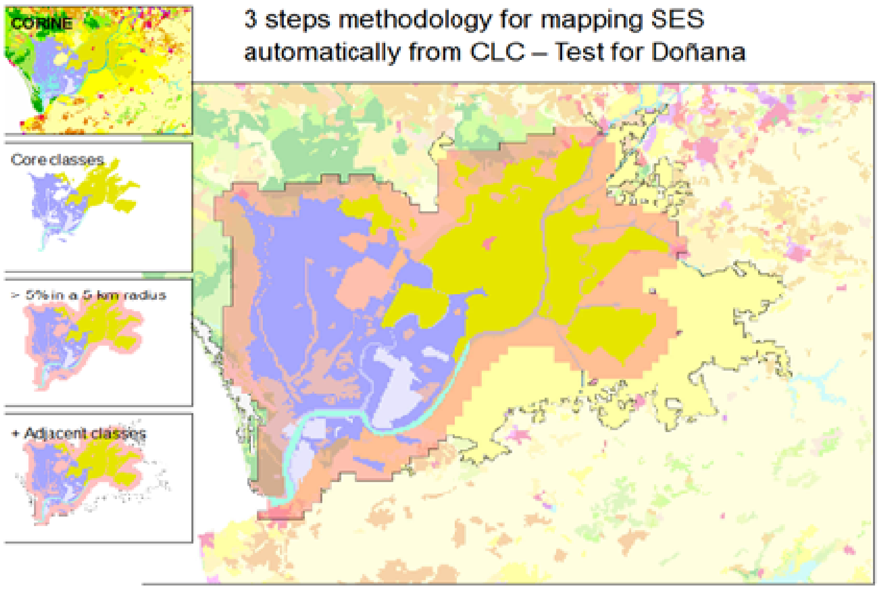


Figure 3.5 Methodology for mapping SES wetlands for accounting

If not in every cases at the level of individual sites, the results are acceptable at least for statistical accounting for coastal regions. Socio-ecosystems have no crisp boundaries, any mapping is a proxy even at the local scale. They can be mapped as administrative entities, groups of municipalities, hydro-morphological systems… The important matter is that these boundaries match correctly to the system which is analyzed; that they surround the typical land cover units and are the core area for the main socio-ecological functions. Accepting fuzzy boundaries for SES means that areas in the periphery may belong as well to some extent to other SES – e.g. the irrigated crops associated to Doñana core area of wetlands. The GIS will be used in this case to avoid double counts.

Of course, the coarse modeling used to at this early stage accounting has just the advantage of allowing a quick start and produce short term accounts. A quality assessment of the map is currently done with MedWet experts. Progressively, modeled boundaries will be substituted with more precise boundaries mapped upon improved data.

Examples of SES maps produced from CLC:

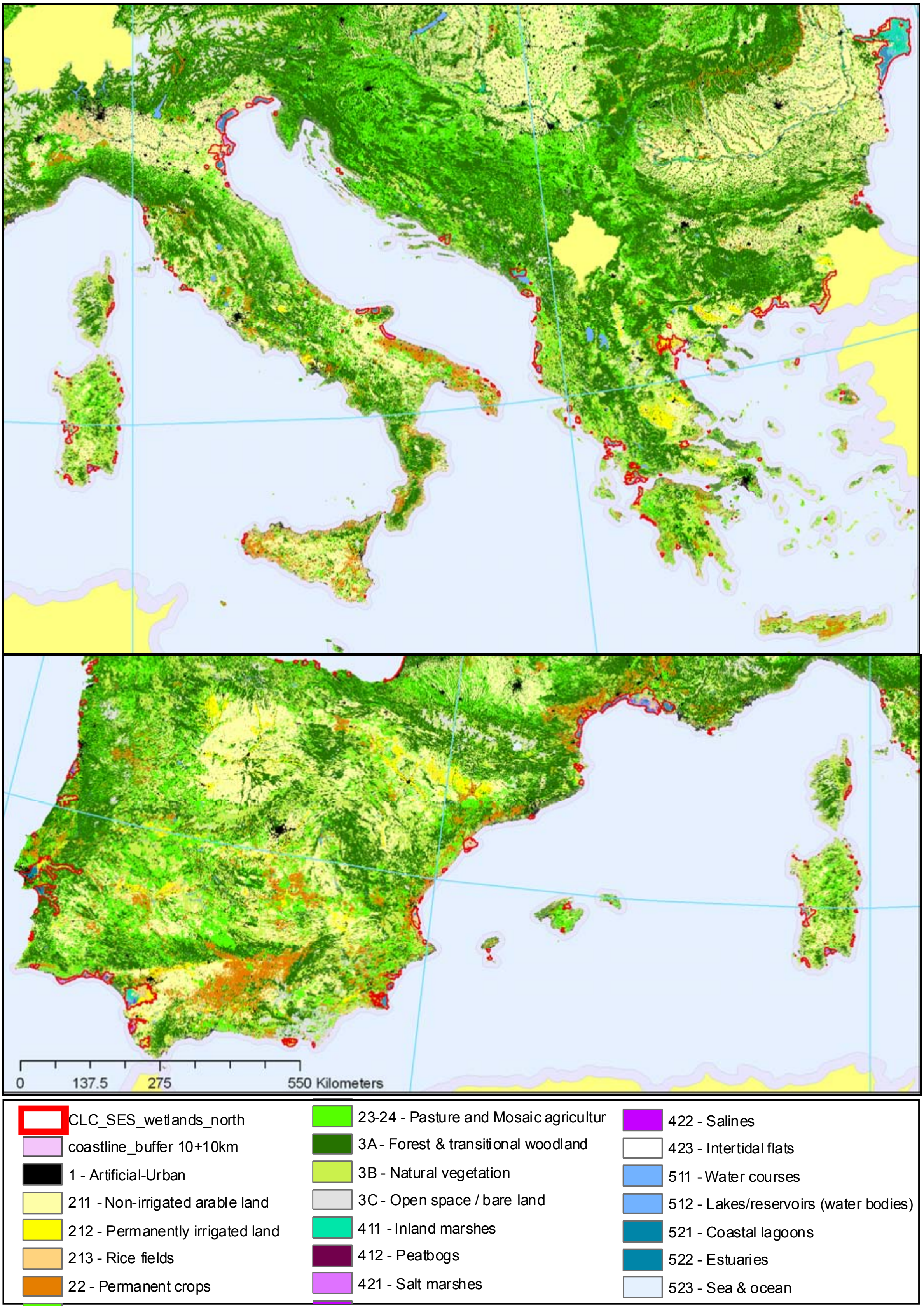

0
137.5
275
550 Kilometers
CLC_SES_wetlands_north
coastline_buffer 10+10km
1 - Artificial-Urban
211 - Non-irrigated arable land
212 - Permanently irrigated land
213 - Rice fields
22 - Permanent crops
23-24 - Pasture and Mosaic agricultur
3A - Forest & transitional woodland
3B - Natural vegetation
3C - Open space / bare land
411 - Inland marshes
412 - Peatbogs
421 - Salt marshes
422 - Salines
423 - Intertidal flats
511 - Water courses
512 - Lakes/reservoirs (water bodies)
521 - Coastal lagoons
522 - Estuaries
523 - Sea & ocean

Figure 3.6: Map of SES Wetlands for the North-East and North-West Mediterranean

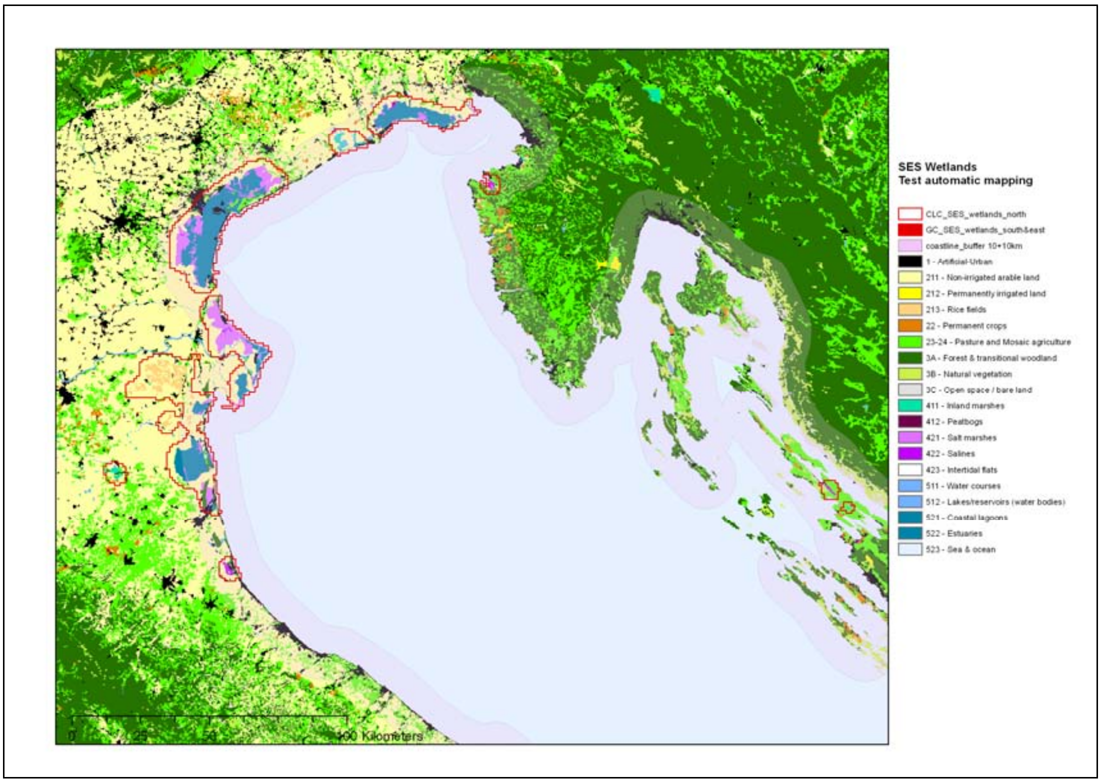


Figure 3.7: Map of SES Wetlands, details for the North Adriatic

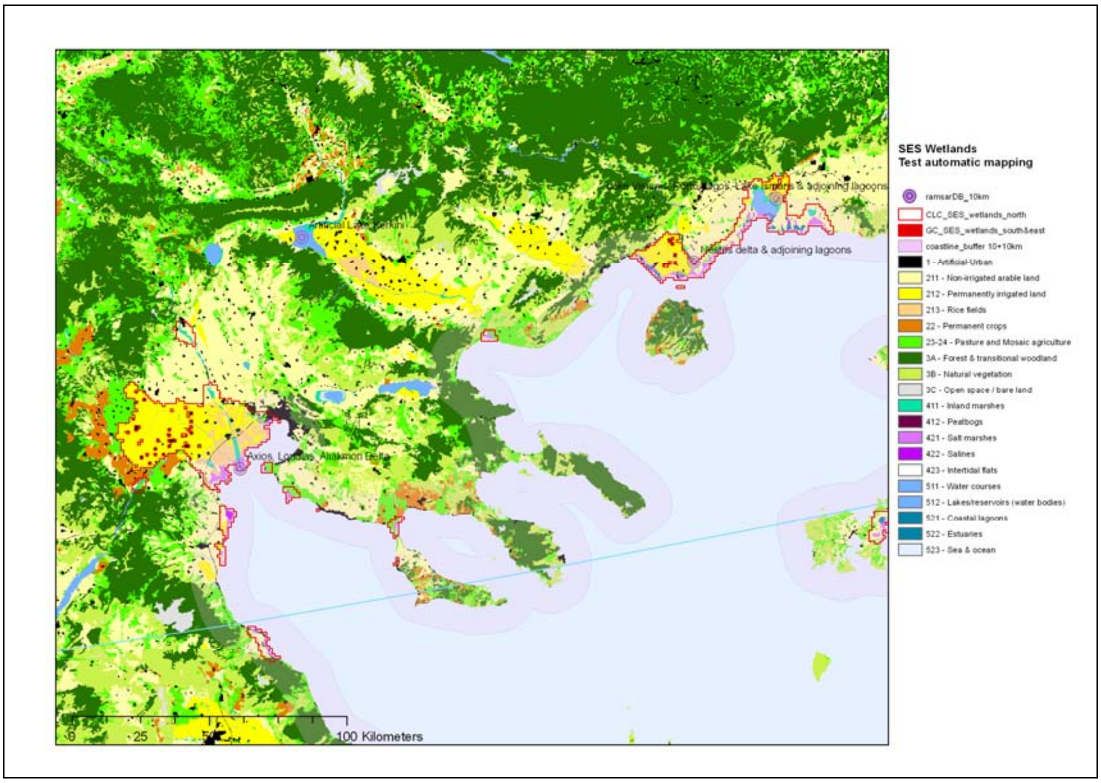


Figure 3.8: Map of SES Wetlands, details for the North Aegean

3.2.3. Maps of the 4 case studies

When coming to the local level, wetland socio-ecosystems may need to be re-mapped for analytical purpose as well as on account of data availability. Some socio-economic data are detailed only by municipalities, other data from sampling are relevant only for the statistical population sampled, as a whole. One progress is expected with the development of gridded statistics, essential at the macro and meso scales for integrating economic, social and ecological dimensions; grids can be helpful at the local level as it will be shown in Chapters 4 and 5.

Maps of the 4 case studies have been considered therefore on several grounds:

- clusters of municipalities;
- perimeter of a national or regional park/ reserve;
- hydro-geo-morphological units.

Chapter 4. Summary accounts of stocks & flows of land cover of European Mediterranean wetland socio-ecosystems

The European Mediterranean is covered now with Corine land cover. 1990 and 2000 are the base years; in addition a special inventory of the 10 km coastal strip has been carried out for 1975 (under projects LaCoast/JRC and Eurosion/DG Environment & EEA). Corine being currently updated for 2006, a 30 years perspective will be given with this medium resolution database. The chapter will present and comment LEAC type accounts and derived aggregates of ecosystem integrity: flows 1990-2000 for the SES wetlands mapped as explained in Chapter 3, grouped by NUTS1, land cover and land cover change 1975-1990-2000 for the 10 km coastal strip and aggregated indicators for SES wetlands grouped by NUTS2.

4.2. Land cover stocks and flows (LEAC), 1975, 1990, 2000

Land cover flows 1990-2000 - Mediterranean Coastal Wetlands Socio-Ecological Systems (SES)

		Bulgaria		Montenegro	Spain		France
		BG1 SEVERNA BULGARIA	BG2 YUZHNA BULGARIA	CS (No NUTS)	ES5 ESTE	ES6 SUR	FR8 MÉDITERRANÉE
lcf11	*Urban development/ infilling*				742	1431	1166
lcf12	*Recycling of developed urban land*				9381	31906	7579
lcf13	*Development of green urban areas*					1590	
lcf21	*Urban dense residential sprawl*				27772	13727	
lcf22	*Urban diffuse residential sprawl*				77804	44414	46216
lcf31	*Sprawl of industrial & commercial sites*				41605	20723	10918
lcf32	*Sprawl of transport networks*				10547		
lcf33	*Sprawl of harbours*				12243	424	2014
lcf34	*Sprawl of airports*				6254		
lcf35	*Sprawl of mines and quarrying areas*					4558	9487
lcf36	*Sprawl of dumpsites*					2915	
lcf37	*Construction*				23267	41552	11872
lcf38	*Sprawl of sport and leisure facilities*				16324	11448	2703
lcf41	*Extension of set aside fallow land and pasture*				13727	58035	
lcf421	*Conversion from arable land to permanent irrigation perimeters*				1431	727849	2756
lcf422	*Other internal conversions of arable land*				8639	151368	
lcf433	*Conversion from olives groves to vineyards and orchards*					1802	15211
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*				583	41764	5512
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*					1113	11024
lcf443	*Conversion from olive groves to non-irrigated arable land*					477	
lcf444	*Diffuse conversion from permanent crops to arable land*				10176	7473	26182
lcf451	*Conversion from arable land to vineyards and orchards*		11554		23479	96672	7261
lcf452	*Conversion from arable land to olive groves*					2067	
lcf461	*Conversion from pasture to permanent irrigation perimeters*						
lcf462	*Intensive conversion from pasture to non-irrigated crop land*						530
lcf463	*Diffuse conversion from pasture to arable and permanent crops*				32171	159530	15158
lcf511	*Intensive conversion from forest to agriculture*				371	33443	2014
lcf512	*Diffuse conversion from forest to agriculture*				371	8056	1166
lcf521	*Intensive conversion from semi-natural land to agriculture*				4611	435925	23267
lcf522	*Diffuse conversion from semi-natural land to agriculture*				2438	49555	477
lcf53	*Conversion from wetlands to agriculture*					25546	3657
lcf54	*Other conversions to agriculture*				371	212	3498
lcf61	*Withdrawal of farming with woodland creation*					2332	
lcf62	*Withdrawal of farming without significant woodland creation*				8533	66303	10971
lcf71	*Conversion from transitional woodland to forest*		689			6095	20882
lcf72	*New forest and woodland creation, afforestation*				3445	28408	24804
lcf73	*Forests internal conversions*					1007	
lcf74	*Recent fellings, re-plantation and other transition*					67204	14204
lcf81	*Water bodies creation*				1060	795	159
lcf82	*Water bodies management*						
lcf91	*Semi-natural creation and rotation*				2120	5830	6148
lcf912	*Semi-natural rotation*					15741	3498
lcf913	*Extension of water courses*						636
lcf92	*Forests and shrubs fires*					265	24486
lcf93	*Coastal erosion*				6625	1272	1537
lcf99	*Other changes and unknown*				6731	78493	12932
	No Change	62805	734739	78705	8289518	18692464	16777574
	TOTAL	62805	746982	78705	8642339	20941784	17107499

Table 4.1 (A) Land cover flows 1990-2000 in European Mediterranean wetlands

Land cover flows 1990-2000 - Mediterranean Coastal Wetlands Socio-Ecological Systems (SES)

		Greece			Croatia	Italy				Romania	Slovenia
		GR1 VOREIA ELLADA	GR2 KENTRIKI ELLADA	GR4 NISIA AIGAIOU, KRITI	HR (No NUTS)	ITD NORD-EST	ITE CENTRO	ITF SUD	ITG ISOLE	RO0 (Sud Est)	SI0 SLOVENIJA
lcf11	*Urban development/ infilling*										
lcf12	*Recycling of developed urban land*									2014	
lcf13	*Development of green urban areas*										
lcf21	*Urban dense residential sprawl*										
lcf22	*Urban diffuse residential sprawl*					8215	954	2067	56392	7314	
lcf31	*Sprawl of industrial & commercial sites*	4134	4293			10971	477		8268	4611	
lcf32	*Sprawl of transport networks*								1590		
lcf33	*Sprawl of harbours*		1166								
lcf34	*Sprawl of airports*	1908				2597					
lcf35	*Sprawl of mines and quarrying areas*		2809						2544	477	
lcf36	*Sprawl of dumpsites*					1961					
lcf37	*Construction*	13038	6943							1219	
lcf38	*Sprawl of sport and leisure facilities*			371		7473	53			4240	
lcf41	*Extension of set aside fallow land and pasture*	5141				7791			424	2438	
lcf421	*Conversion from arable land to permanent irrigation perimeters*	407305	27136			103562			135786		
lcf422	*Other internal conversions of arable land*	753819	82044			41764					
lcf433	*Conversion from olives groves to vineyards and orchards*										
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*										
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*	1007				1855			16854	4611	
lcf443	*Conversion from olive groves to non-irrigated arable land*		583								
lcf444	*Diffuse conversion from permanent crops to arable land*					3710					
lcf451	*Conversion from arable land to vineyards and orchards*					159					
lcf452	*Conversion from arable land to olive groves*								636		
lcf461	*Conversion from pasture to permanent irrigation perimeters*	10123									
lcf462	*Intensive conversion from pasture to non-irrigated crop land*	9911					3975				
lcf463	*Diffuse conversion from pasture to arable and permanent crops*	6466				4717					
lcf511	*Intensive conversion from forest to agriculture*										
lcf512	*Diffuse conversion from forest to agriculture*				795						
lcf521	*Intensive conversion from semi-natural land to agriculture*	7367	2279								
lcf522	*Diffuse conversion from semi-natural land to agriculture*		1219								
lcf53	*Conversion from wetlands to agriculture*	9699	5459							4293	
lcf54	*Other conversions to agriculture*										
lcf61	*Withdrawal of farming with woodland creation*								5194	477	
lcf62	*Withdrawal of farming without significant woodland creation*						1219		81461		
lcf71	*Conversion from transitional woodland to forest*		3286				1855			17808	
lcf72	*New forest and woodland creation, afforestation*						1166				
lcf73	*Forests internal conversions*										
lcf74	*Recent fellings, re-plantation and other transition*		10494			1961	1484	13144		11448	
lcf81	*Water bodies creation*	265				1696					
lcf82	*Water bodies management*	1325									
lcf91	*Semi-natural creation and rotation*					2703	1378		3021		
lcf912	*Semi-natural rotation*	5936							6413	5406	
lcf913	*Extension of water courses*										
lcf92	*Forests and shrubs fires*										
lcf93	*Coastal erosion*	8427	3339			2014	1537				
lcf99	*Other changes and unknown*	10176	2014			3445				6996	
	No Change	11266104	7953021	490303	1264209	13217829	1605052	3186254	4836356	25116541	123543
	TOTAL	12522151	8106085	490674	1265004	13424423	1619150	3201465	5154939	25189893	123543

Table 4.1 (B) Land cover flows 1990-2000 in European Mediterranean wetlands

The table of flows accounts refers to the land cover accounts methodology published by the EEA. Flows group the 1936 possible 1 to 1 individual changes of the Corine matrix according to a limited number of processes which can be understood and interpreted. If necessary, flows can be cross analysed with land cover types. The results here are presented by NUTS 1, an administrative breakdown mostly used for land planning. The structure of the data base where land cover and change are gridded at resolutions of 1 hectare x 1 hectare, and then aggregated into 1km x1 km for fast calculations and integration with other types of data (socio-economic statistics, meteorology etc…).

The tables are expressed here in hectares. They show on the average limited changes but, in some regions, significant conversions which may impact the integrity and health of the wetlands.

Urban sprawl (residence and infrastructures) is noticeable during that period in Mediterranean wetland SES of Spain as well as (to a minor extent) in France and Italy.

The extension of irrigation perimeters (lcf421) which are often in competition for water with wetlands is very important in the South of Spain, in Greece and North East Italy.

Conversion of wetlands to agriculture (lcf53) is more limited but still taking place, which is somehow surprising for ecosystems widely protected. It is going together with a continuation of the conversion of other natural or semi-natural land to agriculture. The phenomenon in costal areas has been analysed as an indirect consequence of urban sprawl over crop land, which pushes farmers to cultivating marginal land for maintaining their activity in the area.

Socio-ecosystem wetlands and/or natural parks where forest is a significant land cover show up an important rotation of felling and plantation. The apparently balanced situation should be scrutinized regarding risks of impoverishment of the habitats.

4.3. Land cover flows, stocks and change (LEAC), 1975, 1990, 2000 – 10 km coastal strip

A large part of European wetlands are located alongside the coast, particularly in the Mediterranean. The analysis of the land cover flows on the coastal strip from 1975 is therefore of high interest.

On interesting finding is that when comparing the 2 periods 1975-1990 and 1990-2000, the speed of land cover changes has slowed down in France and in Italy but oppositely has increased in Spain.

Detailed tables present the results. Although the fact that the 1975 inventories follow the Corine methodology, they don't present the same detail. Therefore, separate analysis of change has to be carried out for the 2 periods. As well, more detail is available for wetlands in 1990 and 2000. The tables are:

- Table 4.2 Land cover flows 1975-1990-2000
- Table 4.3 Land cover 2000 and 1990 (Corine land cover)
- Table 4.4 Land cover 1990 and 1975 (Source: Lacoast and Eurosion)
- Table 4.5 (A) Land cover 2000 – with details for wetlands
- Table 4.5 (B) Land cover 1990 – with details for wetlands

Flows 1990-2000 - 10 km strip

NUTS0	NUTS1	LCF1 Urban land management	LCF2 Urban residential sprawl	LCF3 Sprawl of economic sites and infrastructures	LCF4 Agriculture internal conversions	LCF5 Conversion of land to agriculture: LCF51 Conversion from forest to agriculture	LCF5 Conversion of land to agriculture: LCF52 Conversion from semi-natural land to agriculture	LCF5 Conversion of land to agriculture: **LCF53 Conversion from wetlands to agriculture**	LCF5 Conversion of land to agriculture: LCF54 Other conversion to agriculture	LCF6 Withdrawal of farming	LCF7 Forests creation and management	LCF8 Water bodies creation and management	LCF9 Changes of Land Cover due to natural and multiple causes	NC No Change	***Grand Total***
	ES5 ESTE	1736	15989	13642	7403	1101	2115		157	1533	7497	30	8754	1143057	***1203014***
	ES6 SUR	1701	2582	6206	22807	4362	15513	**81**	13	1303	14416	129	5674	903196	***977983***
ES SPAIN Total		3437	18571	19848	30210	5463	17628	**81**	170	2836	21913	159	14428	2046253	***2180997***
	FR8 MÉDITERRANÉE	499	4420	3107	1754	763	1303	**33**		449	12078	109	11530	1015728	***1051773***
FR FRANCE Total		499	4420	3107	1754	763	1303	**33**		449	12078	109	11530	1015728	***1051773***
	ITC NORD-OVEST		15	119						452	3718		1615	263730	***269649***
	ITD NORD-EST	47	616	614	893						123	48	169	365842	***368352***
	ITE CENTRO (I)	243	1695	1683	1932					291	2137		708	738477	***747166***
	ITF SUD	63	4748	3232	9111	787	849	**40**	10	2562	1589	58	862	1837746	***1861657***
	ITG ISOLE	42	5563	1703	3333		468			18938	2292		5724	1654452	***1692515***
IT ITALY Total		395	12637	7351	15269	787	1317	**40**	10	22243	9859	106	9078	4860247	***4939339***
Grand Total		**4331**	**35628**	**30306**	**47233**	**7013**	**20248**	**154**	**180**	**25528**	**43850**	**374**	**35036**	**7922228**	***8172109***

Flows 1975-1990 LaCoast - 10 km strip

NUTS0	NUTS1	LCF1 Urban land management	LCF2 Urban residential sprawl	LCF3 Sprawl of economic sites and infrastructures	LCF4 Agriculture internal conversions	LCF5 Conversion of land to agriculture: LCF51 Conversion from forest to agriculture	LCF5 Conversion of land to agriculture: LCF52 Conversion from semi-natural land to agriculture	LCF5 Conversion of land to agriculture: **LCF53 Conversion from wetlands to agriculture**	LCF5 Conversion of land to agriculture: LCF54 Other conversion to agriculture	LCF6 Withdrawal of farming	LCF7 Forests creation and management	LCF8 Water bodies creation and management	LCF9 Changes of Land Cover due to natural and multiple causes	NC No Change	***Grand Total***
	ES5 ESTE	3597	4183	2582	8878	638	1915	**1648**	23	4115	11855		6414	719258	***765106***
	ES6 SUR	1544	11102	6870	33778	7931	26646	**114**	21	14606	24646	71	20305	726340	***873974***
ES SPAIN Total		5141	15285	9452	42656	8569	28561	**1762**	44	18721	36501	71	26719	1445598	***1639080***
	FR8 MÉDITERRANÉE	899	10537	2723	11959		1796	**139**	48	2237	4248	114	9057	956284	***1000041***
FR FRANCE Total		899	10537	2723	11959		1796	**139**	48	2237	4248	114	9057	956284	***1000041***
	ITC NORD-OVEST	132	1377	681	47	1720	1132	**30**	80	2252	10658		3594	231744	***253447***
	ITD NORD-EST	418	2791	2526	2257	1165	189	**255**	223	703	1237	419	10963	327001	***350147***
	ITE CENTRO (I)	1304	7741	6250	50548	2525	8515	**281**	244	3469	3563	102	8777	566449	***659768***
	ITF SUD	7651	12401	8777	114589	16718	30758	**19**	1516	34455	41755	355	10695	1458456	***1738145***
	ITG ISOLE	587	21572	8419	12877	7611	17264	**861**	921	9872	16051	1038	19993	1433102	***1550168***
IT ITALY Total		10092	45882	26653	180318	29739	57858	**1446**	2984	50751	73264	1914	54022	4016752	***4551675***
Grand Total		**16132**	**71704**	**38828**	**234933**	**38308**	**88215**	**3347**	**3076**	**71709**	**114013**	**2099**	**89798**	**6418634**	***7190796***

Table 4.2 Land cover flows 1975-1990-2000 in European Mediterranean coastal strip

2000 CLC LEAC - 10 km strip

NUTS0	NUTS1	1 Artificial areas	211 Non-irrigated arable land	212 Permanently irrigated land	213 Rice fields	221 Vineyards	222 Fruit trees and berry plantations	223 Olive groves	241 Annual crops associated with permanent crops	**_2A Arable land & permanent crops Total_**	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	**4 Wetlands**	**5 Water bodies**	**_Grand Total_**
			2A Arable land & permanent crops														
	ES5 ESTE	142693	43176	55150	40681	13931	169819	23586	64310	**_410653_**	195006	247413	165416	18661	**13943**	**9229**	**_1203014_**
	ES6 SUR	64253	70315	113206	11275	7358	50904	2763	251	**_256072_**	129634	137805	178225	130083	**53318**	**28593**	**_977983_**
ES SPAIN Total		206946	113491	168356	51956	21289	220723	26349	64561	**_666725_**	324640	385218	343641	148744	**67261**	**37822**	**_2180997_**
	FR8 MÉDITERRANÉE	128461	18074		6859	94501	9734	146		**_129314_**	116672	211407	308770	48645	**47403**	**61101**	**_1051773_**
FR FRANCE Total		128461	18074		6859	94501	9734	146		**_129314_**	116672	211407	308770	48645	**47403**	**61101**	**_1051773_**
	ITC NORD-OVEST	23657	3130			396		11982	70	**_15578_**	38515	162822	21799	7000	**62**	**216**	**_269649_**
	ITD NORD-EST	32001	172945		1240	776	902	122	101	**_176086_**	29447	25274	984	3428	**29297**	**71835**	**_368352_**
	ITE CENTRO (I)	74193	282201			5719	4007	12232	4471	**_308630_**	156720	140774	42683	12559	**4649**	**6958**	**_747166_**
	ITF SUD	133410	388141	13264		70494	57508	335506	107857	**_972770_**	315910	298442	93369	26055	**7802**	**13899**	**_1861657_**
	ITG ISOLE	135476	318373		3060	73188	82589	134976	14924	**_627110_**	230758	154971	485261	33014	**12438**	**13487**	**_1692515_**
IT ITALY Total		398737	1164790	13264	4300	150573	145006	494818	127423	**_2100174_**	771350	782283	644096	82056	**54248**	**106395**	**_4939339_**
Grand Total		**734144**	**1296355**	**181620**	**63115**	**266363**	**375463**	**521313**	**191984**	**_2896213_**	**1212662**	**1378908**	**1296507**	**279445**	**168912**	**205318**	**_8172109_**

1990 CLC LEAC - 10 km strip

NUTS0	NUTS1	1 Artificial areas	211 Non-irrigated arable land	212 Permanently irrigated land	213 Rice fields	221 Vineyards	222 Fruit trees and berry plantations	223 Olive groves	241 Annual crops associated with permanent crops	**_2A Arable land & permanent crops Total_**	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	**4 Wetlands**	**5 Water bodies**	**_Grand Total_**
			2A Arable land & permanent crops														
	ES5 ESTE	113486	44977	57412	40743	14617	171069	23840	66572	**_419230_**	206038	252108	174885	13240	**13957**	**10070**	**_1203014_**
	ES6 SUR	55577	77665	100396	9693	7544	44808	2928	212	**_243246_**	129791	141593	188900	137589	**52401**	**28886**	**_977983_**
ES SPAIN Total		169063	122642	157808	50436	22161	215877	26768	66784	**_662476_**	335829	393701	363785	150829	**66358**	**38956**	**_2180997_**
	FR8 MÉDITERRANÉE	121161	17854		6769	95631	9615	146		**_130015_**	119257	209993	307753	54926	**47538**	**61130**	**_1051773_**
FR FRANCE Total		121161	17854		6769	95631	9615	146		**_130015_**	119257	209993	307753	54926	**47538**	**61130**	**_1051773_**
	ITC NORD-OVEST	23523	3130			396		11982	70	**_15578_**	39050	162203	23061	5920	**62**	**252**	**_269649_**
	ITD NORD-EST	30771	173705		1084	773	979	122	101	**_176764_**	29790	25332	984	3414	**29382**	**71915**	**_368352_**
	ITE CENTRO (I)	70789	283868			5373	4120	12398	4511	**_310270_**	158657	140588	43099	12151	**4649**	**6963**	**_747166_**
	ITF SUD	125440	391370	13264		70477	57536	338905	108152	**_979704_**	316609	298877	93475	25549	**7817**	**14186**	**_1861657_**
	ITG ISOLE	128410	325331		1472	74239	83075	136006	14935	**_635058_**	244537	153846	472094	32591	**12438**	**13541**	**_1692515_**
IT ITALY Total		378933	1177404	13264	2556	151258	145710	499413	127769	**_2117374_**	788643	780846	632713	79625	**54348**	**106857**	**_4939339_**
Grand Total		**669157**	**1317900**	**171072**	**59761**	**269050**	**371202**	**526327**	**194553**	**_2909865_**	**1243729**	**1384540**	**1304251**	**285380**	**168244**	**206943**	**_8172109_**

Table 4.3 Land cover 2000 and 1990 in European Mediterranean coastal strip (Corine land cover)

1990 LaCoast - 10 km strip

NUTS0	NUTS1	1 Artificial areas	2A Arable land & permanent crops: 211 Non-irrigated arable land	212 Permanently irrigated land	213 Rice fields	221 Vineyards	222 Fruit trees and berry plantations	223 Olive groves	241 Annual crops associated with permanent crops	**2A Arable land & permanent crops Total**	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	**4 Wetlands**	**5 Water bodies**	**Grand Total**
	ES5 ESTE	84811	22959	46824	36975	12773	132836	18314	27	270708	141292	120877	118330	9274	10338	9476	765106
	ES6 SUR	53670	63666	103138		6521	26414	3112	299	203150	128650	124336	154983	153644	38309	17232	873974
ES SPAIN Total		138481	86625	149962	36975	19294	159250	21426	326	473858	269942	245213	273313	162918	48647	26708	1639080
	FR8 MÉDITERRANÉE	101611	15952		5962	112927	6223	753	1963	143780	103444	131286	365358	55800	40604	58158	1000041
FR FRANCE Total		101611	15952		5962	112927	6223	753	1963	143780	103444	131286	365358	55800	40604	58158	1000041
	ITC NORD-OVEST	20584	1208			599		25551	2281	29639	33743	144408	22914	1804	18	337	253447
	ITD NORD-EST	29463	160364		850	1117	781	98	104	163314	30038	22953	2957	3058	25205	73159	350147
	ITE CENTRO (I)	63766	245185	1018		5191	5057	9703	5384	271538	143297	115182	40633	13910	4375	7067	659768
	ITF SUD	107763	245872	131799	239	44860	63571	326365	140412	953118	302769	262560	66257	25357	5887	14434	1738145
	ITG ISOLE	108187	186546	27783	1770	63373	68081	119989	23869	491411	377151	221307	258236	71051	11842	10983	1550168
IT ITALY Total		329763	839175	160600	2859	115140	137490	481706	172050	1909020	886998	766410	390997	115180	47327	105980	4551675
Grand Total		**569855**	**941752**	**310562**	**45796**	**247361**	**302963**	**503885**	**174339**	**2526658**	**1260384**	**1142909**	**1029668**	**333898**	**136578**	**190846**	**7190796**

1975 LaCoast - 10 km strip

NUTS0	NUTS1	1 Artificial areas	2A Arable land & permanent crops: 211 Non-irrigated arable land	212 Permanently irrigated land	213 Rice fields	221 Vineyards	222 Fruit trees and berry plantations	223 Olive groves	241 Annual crops associated with permanent crops	**2A Arable land & permanent crops Total**	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	**4 Wetlands**	**5 Water bodies**	**Grand Total**
	ES5 ESTE	78222	22888	48658	34240	12872	131439	18635	27	268759	147511	126508	110426	12003	12181	9496	765106
	ES6 SUR	35789	66039	66273		9409	28414	4620	520	175275	150404	140120	160492	154827	39563	17504	873974
ES SPAIN Total		114011	88927	114931	34240	22281	159853	23255	547	444034	297915	266628	270918	166830	51744	27000	1639080
	FR8 MÉDITERRANÉE	88397	13323		5944	122659	5488	758	1378	149550	105839	136716	368580	51710	40895	58354	1000041
FR FRANCE Total		88397	13323		5944	122659	5488	758	1378	149550	105839	136716	368580	51710	40895	58354	1000041
	ITC NORD-OVEST	18717	1229			597		25156	2276	29258	34425	145485	21330	3749	21	462	253447
	ITD NORD-EST	24612	163049	12	888	1252	656	98	119	166074	30778	24343	2796	3435	32014	66095	350147
	ITE CENTRO (I)	50198	231072	14554		4286	5072	9752	6771	271507	155608	118866	41293	10930	4721	6645	659768
	ITF SUD	88242	240990	127222	136	36086	43829	299861	133510	881634	398362	252561	64123	33214	5895	14114	1738145
	ITG ISOLE	80025	189214	27817	1745	60766	68038	116910	22926	487416	389173	227606	273970	68754	12587	10637	1550168
IT ITALY Total		261794	825554	169605	2769	102987	117595	451777	165602	1835889	1008346	768861	403512	120082	55238	97953	4551675
Grand Total		**464202**	**927804**	**284536**	**42953**	**247927**	**282936**	**475790**	**167527**	**2429473**	**1412100**	**1172205**	**1043010**	**338622**	**147877**	**183307**	**7190796**

Table 4.4 Land cover 1990 and 1975 in European Mediterranean coastal strip (Source: Lacoast and Eurosion)

Mediterranean coastal 10 km strip - Land cover 2000

Hectares		1 Artificial areas	2A Arable land & permanent crops	of which: 212 Permanently irrigated land	of which: 213 Rice fields	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	*4 Wetlands*: ***411 Inland marshes***	***421 Salt marshes***	***422 Salines***	***423 Intertidal flats***	5 Water bodies: 511 Water courses	***512 Lakes & Reservoirs***	***521 Coastal lagoons***	***522 Estuaries***	523 Sea and Ocean	Total
NUTS0	*NUTS1*																		
	BG1 SEVERNA BULGARIA	13556	82136			18776	30208	2256	1209	***436***	***33***			124	***1845***				150579
	BG2 YUZHNA BULGARIA	9974	47185			14213	68043	7242	791	***1769***		***799***		47	***6957***	***365***			157385
BG BULGARIA Total		23530	129321			32989	98251	9498	2000	***2205***	***33***	***799***		171	***8802***	***365***			307964
	ES5 ESTE	142693	410653	*55150*	*40681*	195006	247413	165416	18661	***989***	***9511***	***3443***		1947	***510***	***6624***		148	1203014
	ES6 SUR	64253	256072	*113206*	*11275*	129634	137805	178225	130083	***21576***	***14240***	***16167***	***1335***	1748	***6933***	***13533***	***6379***		977983
ES SPAIN Total		206946	666725	*168356*	*51956*	324640	385218	343641	148744	***22565***	***23751***	***19610***	***1335***	3695	***7443***	***20157***	***6379***	148	2180997
	FR8 MÉDITERRANÉE	128461	129314		*6859*	116672	211407	308770	48645	***1419***	***37382***	***8602***		2850	***1345***	***56877***		29	1051773
FR FRANCE Total		128461	129314		*6859*	116672	211407	308770	48645	***1419***	***37382***	***8602***		2850	***1345***	***56877***		29	1051773
	GR1 VOREIA ELLADA	38351	292040	*42728*	*13474*	146169	242273	174572	8965	***5554***	***20969***	***877***		2554	***5018***	***2858***	***180***	160	940540
	GR2 KENTRIKI ELLADA	45925	461123	*64759*	*3617*	550740	403660	730921	27041	***3157***	***11522***	***3736***		1758	***3214***	***15540***	***233***	65	2258635
	GR3 ATTIKI	43648	21551			84374	68040	87715	2239	***128***	***25***	***50***			***163***				307933
	GR4 NISIA AIGAIOU, KRITI	25931	253028	*52*		321283	164770	703260	44781		***1353***	***652***			***295***	***434***			1515787
GR GREECE Total		153855	1027742	*107539*	*17091*	1102566	878743	1696468	83026	***8839***	***33869***	***5315***		4312	***8690***	***18832***	***413***	225	5022895
HR CROATIA		53564	49245	*5290*		323997	531993	153113	56666	***2485***	***525***	***532***	***47***	868	***6149***	***44***			1179228
	ITC NORD-OVEST	23657	15578			38515	162822	21799	7000	***62***				176			***40***		269649
	ITD NORD-EST	32001	176086		*1240*	29447	25274	984	3428	***1642***	***26143***	***1512***		4893	***1768***	***64978***	***143***	53	368352
	ITE CENTRO (I)	74193	308630			156720	140774	42683	12559	***3702***	***871***	***76***		930	***3074***	***2925***		29	747166
	ITF SUD	133410	972770	*13264*		315910	298442	93369	26055	***63***	***3032***	***4707***		280	***982***	***12637***			1861657
	ITG ISOLE	135476	627110		*3060*	230758	154971	485261	33014	***770***	***7983***	***3685***		2694	***2084***	***8640***	***69***		1692515
IT ITALY Total		398737	2100174	*13264*	*4300*	771350	782283	644096	82056	***6239***	***38029***	***9980***		8973	***7908***	***89180***	***252***	82	4939339
	RO02 Sud-Est	16882	65896			4469	3966	9825	9813	***76463***	***815***			2207	***15889***	***39023***			245248
RO ROMANIA Total		16882	65896			4469	3966	9825	9813	***76463***	***815***			2207	***15889***	***39023***			245248
SI SLOVENIA		2504	1241			14990	25929	225		***119***	***100***	***491***			***66***				45665
Grand Total		984479	4169658	*294449*	*80206*	2691673	2917790	3165636	430950	***120334***	***134504***	***45329***	***1382***	23076	***56292***	***224478***	***7044***	484	14973109

Table 4.5 (A) Land cover 2000 in European Mediterranean coastal strip – with details for wetlands

Mediterranean coastal 10 km strip - Land cover 1990

Hectares		1 Artificial areas	2A Arable land & permanent crops	of which: 212 Permanently irrigated land	of which: 213 Rice fields	2B Pastures & mosaics	3A Forested land	3B Semi-natural vegetation	3C Open spaces/ bare soils	4 Wetlands: 411 Inland marshes	4 Wetlands: 421 Salt marshes	4 Wetlands: 422 Salines	4 Wetlands: 423 Intertidal flats	5 Water bodies: 511 Water courses	5 Water bodies: 512 Lakes & Reservoirs	5 Water bodies: 521 Coastal lagoons	5 Water bodies: 522 Estuaries	5 Water bodies: 523 Sea and Ocean	Total
NUTS0	*NUTS1*																		
	BG1 SEVERNA BULGARIA	13498	82134			18817	30219	2264	1209	436	33			124	1845				150579
	BG2 YUZHNA BULGARIA	9948	47214			14184	68043	7268	791	1769		799		47	6957	365			157385
BG BULGARIA Total		23446	129348			33001	98262	9532	2000	2205	33	799		171	8802	365			307964
	ES5 ESTE	113486	419230	57412	40743	206038	252108	174885	13240	989	9531	3437		1947	480	6609		1034	1203014
	ES6 SUR	55577	243246	100396	9693	129791	141593	188900	137589	21641	14615	14796	1349	1642	6927	13533	6414	370	977983
ES SPAIN Total		169063	662476	157808	50436	335829	393701	363785	150829	22630	24146	18233	1349	3589	7407	20142	6414	1404	2180997
	FR8 MÉDITERRANÉE	121161	130015		6769	119257	209993	307753	54926	1419	37517	8602		2838	1236	56869		187	1051773
FR FRANCE Total		121161	130015		6769	119257	209993	307753	54926	1419	37517	8602		2838	1236	56869		187	1051773
	GR1 VOREIA ELLADA	35545	294590	39172	10855	144712	236388	182669	8055	5620	21311	877		2554	4949	3050	180	40	940540
	GR2 KENTRIKI ELLADA	40684	461286	64515	3334	551261	403912	735049	26692	3244	11640	3715		1765	3507	15540	233	107	2258635
	GR3 ATTIKI	39152	22683			86264	68638	89546	1175	135	25	50			187			78	307933
	GR4 NISIA AIGAIOU, KRITI	23291	253981	52		316921	165514	708588	44809		1353	652			200	434		44	1515787
GR GREECE Total		138672	1032540	103739	14189	1099158	874452	1715852	80731	8999	34329	5294		4319	8843	19024	413	269	5022895
HR CROATIA		52898	49301	5290		321113	535272	152576	57383	2485	525	532	47	868	6184	44			1179228
	ITC NORD-OVEST	23523	15578			39050	162203	23061	5920	62				176			40	36	269649
	ITD NORD-EST	30771	176764		1084	29790	25332	984	3414	1642	26228	1512		4893	1720	64978	143	181	368352
	ITE CENTRO (I)	70789	310270			158657	140588	43099	12151	3702	871	76		930	3074	2925		34	747166
	ITF SUD	125440	979704	13264		316609	298877	93475	25549	78	3032	4707		280	976	12841		89	1861657
	ITG ISOLE	128410	635058		1472	244537	153846	472094	32591	770	7983	3685		2694	2084	8640	69	54	1692515
IT ITALY Total		378933	2117374	13264	2556	788643	780846	632713	79625	6254	38114	9980		8973	7854	89384	252	394	4939339
	RO02 Sud-Est	15930	66441			4780	3966	9825	9813	76559	815			2207	15889	39023			245248
RO ROMANIA Total		15930	66441			4780	3966	9825	9813	76559	815			2207	15889	39023			245248
SI SLOVENIA		2403	1241			14997	25899	228	121	119	100	491			66				45665
Grand Total		902506	4188736	280101	73950	2716778	2922391	3192264	435428	120670	135579	43931	1396	22965	56281	224851	7079	2254	14973109

Table 4.5 (B) Land cover 1990 in European Mediterranean coastal strip – with details for wetlands

4.4. From land cover to ecosystem and ecosystem services accounts

4.4.1. Aggregated landscape physical indicators (state and change 1990-2000)

In addition to monitoring (and accounting for) land cover change, Corine land cover has been used for spatial modelling in order to assess landscape potentials for supporting biodiversity and pressures on these landscapes. For this kind of macro assessments, the focus is on the importance (or weight, potential, temperature, influence, attraction …) of geographical objects on the land that they cover as well as in their neighbourhood. Technically, maps are derived from land cover and other maps by smoothing the real value within a grid (commonly 1km² grid or 1 ha for some applications), giving them a value to neighbouring grid cells decreasing with the distance from the core cell. A formula commonly used shrines the neighbouring values with the square of the distance between cells, the calculation being limited to a span of 5, 10 or 20 km. The methodology is detailed in the EEA report 11-2006, *"Land cover accounts for Europe 1990-2000"*. Smoothed layers of Corine land cover have been computed for 1990 and 2000 and are disseminated by the EEA dataservice under the acronym of CORILIS. On particular mathematical property of the CORILIS layers is that they are additive, the total of the values of the different classes expressed in %age being 100 in each and every grid cell.

Using the same reference grid, similar computations can be made for any variables such as various zonings (e.g. nature protection) or statistics (e.g. population).

The indicators used in ecosystem accounting are first of all strictly based on Corine/CORILIS. They are principally:

- Urban temperature, which describes the pressure of urban and artificial land use within and in the neighbourhood of an ecosystem.
- Intensive agriculture temperature, the same for broad pattern arable land and permanent crops.
- The total of the 2 indicators is the temperature of intensive land use. Its supplement to 100 is called the Green Background Landscape Index (GBLI) which maps and measures the landscapes more favourable to nature, because of their own naturalness (forests, wetlands…) or their capacity of supporting ecological networks (pasture and mosaic agriculture). GBLI is as well the sum of the corresponding Corine/CORILIS classes and can be decomposed if there is any need to set aside a particular class (e.g. plantations of eucalyptus, intensively managed large pasture areas…). Simple (but reproducible and modifiable), GBLI is a first proxy of landscape potentials related to nature.

One limitation of GBLI is that it is based on satellite images (which allow exhaustiveness and repetitive monitoring) which ignore the local complexity of landscapes and the richness of the biodiversity that they host. In order to overcome the difficulty, an indicator is produced on the basis of the information collected for nature conservation. At the macro level, a first simple indicator reflect the designation of areas for European or national protection: this is the result of intensive field work by scientists and political action environmental agencies involving significant budgetary costs. There is there therefore a serious presumption that the designated areas have a high ecological value. Technically, various designation maps are merged (to bypass heterogeneity resulting from political strategies) and smoothed to reflect some importance of these areas in their neighbourhood. The dataset is named NATURILIS.

Adding GBLI and Naturilis gives a better picture which reflects various situations such as:

- green landscape which is designated : the highest value
- green landscape which is no designated because of more common habitats: some value anyway given by GBLI but less than the previous case
- intensively used landscape (low GBLI) where niches host rare or endangered species, and which are therefore designated for conservation: their value is captured by the NATURILIS index.
- intensively used landscape which are not designated and which are considered as having a lower ecological value

In this approximation process, an important element is still missing and relates to the functioning of landscapes. The solution is to incorporate an adequate indicator of fragmentation. The solution currently used is the measurement of the Effective Mesh Size (MEFF). The MEFF value can be interpreted as the expected size of the area that is accessible when starting a movement at a randomly chosen point inside the reporting unit (in our case 1km grid) without encountering a physical barrier. So the higher is the MEFF value, the less fragmented is the area around.

When combining GBLI, NATURLIS and MEFF, we get an aggregate which captures important aspects of ecosystem integrity. This aggregate is named Net Landscape Ecological Potential (NLEP). It can be monitored and produce a first overall assessment of the ecosystems condition.

Of course, not all important aspects are incorporated at this stage and the indicator has to be supplemented with 4 other indicators (and accounts) : a species based indicator (designated areas may face changes), an indicator of net primary productivity, an indicators of river ecosystems and an indicator taking stock of the small features not observed by satellite imagery. Elements of such indicators are presented in the local case studies.

These are macro indicators, which implementation has started at the European scale and which could be implemented at the global level in the context of the global Earth observation programmes. They can be as well downscaled to the regional and local levels and provide important gateways between the levels of policy framing and assessment and the levels of action.

4.4.2. Result for the Mediterranean Wetlands (state and change 1990-2000)

Maps and tables […]

LEAC Aggregates - Coastal Wetlands Socio-Ecological Systems (SES)

		TOTAL VALUES IN SES								
	Surface of coastal SES Wetlands	Urban temperature 2000	Change in Urban temperature 1990-2000	Intensive Agriculture Temperature 2000	Change in Intensive Agriculture temperature 1990-2000	Landscape Net Ecological Potential 2000	Change in Landscape Net Ecological Potential 1990-2000	Nature designation index (combined N2000 & national)	Effective Mesh Size 2005	Population 2000
UNITS	km²	0-100	0-100	0-100	0-100	0-100	0-100	0-100	logN(MEFF)	inhabitants
Coastal Regions with SES Wetlands	SURF_SES_WET1	URB_TEMP_2	URB_TEMP_9	XB_TEMP_20	XB_TEMP_90	LNEP2000	LNEP_90_00	NATURILIS_	LNMEFF	POPCLC_200
BG13 Severoiztochen	17	95	2	1048	3	n.a.	n.a.	403	n.a.	424
BG23 Yugoiztochen	175	2027	17	6068	8	n.a.	n.a.	2880	n.a.	46782
CS Montenegro	452	246		112	58	n.a.	n.a.	n.a.	n.a.	n.a.
ES51 Cataluña	695	5311	683	41856	-166	32213	-1394	5792	84997	78024
ES52 Comunidad Valenciana	898	8172	3339	44542	-954	50137	-2818	18103	99419	362467
ES53 Illes Balears	203	836	218	8480	-266	12234	-285	4150	21190	23383
ES61 Andalucía	3444	12366	1214	163530	8597	253612	-19665	57176	561423	648731
ES62 Región de Murcia	622	3480	1008	34207	-456	18706	-744	9210	57329	90007
FR81 Languedoc-Roussillon	1636	13668	390	48984	1100	122391	-2769	50773	183593	228648
FR82 Provence-Alpes-Côte d'Azur	1601	11067	398	35713	1168	133527	-2867	56326	194389	247076
FR83 Corse	195	1254	17	4944	-101	14086	-230	2113	20795	8673
GR11 Anatoliki Makedonia, Thraki	1154	2221	n.a.	69263	1974	n.a.	n.a.	26887	n.a.	37501
GR12 Kentriki Makedonia	1343	5752	n.a.	103138	303	n.a.	n.a.	14647	n.a.	101312
GR14 Thessalia	51	233	n.a.	2564	35	n.a.	n.a.	608	n.a.	2932
GR21 Ipeiros	442	814	n.a.	9401	186	n.a.	n.a.	12778	n.a.	17687
GR22 Ionia Nisia	67	464	n.a.	1312	-35	n.a.	n.a.	944	n.a.	15557
GR23 Dytiki Ellada	956	1742	n.a.	39083	21	n.a.	n.a.	23847	n.a.	42079
GR24 Sterea Ellada	172	262	n.a.	10243	19	n.a.	n.a.	6018	n.a.	14126
GR25 Peloponnisos	138	514	n.a.	5183	79	n.a.	n.a.	1381	n.a.	12749
GR41 Voreio Aigaio	105	53	n.a.	4478	105	n.a.	n.a.	3084	n.a.	2200
GR42 Notio Aigaio	12	20	n.a.	85	-3	n.a.	n.a.	100	n.a.	524
HR Croatia	254	646	n.a.	2294	-176	n.a.	n.a.	81	n.a.	27553
ITD3 Veneto	1416	7340	263	45310	147	121929	-2390	34382	208703	254750
ITD4 Friuli-Venezia Giulia	335	1187	41	12291	685	27751	-560	8334	49235	26210
ITD5 Emilia-Romagna	917	3559	156	59884	-125	43363	-2379	15961	129537	85179
ITE1 Toscana	345	2499	-90	9459	223	26005	-538	11567	39544	45332
ITF4 Puglia	673	1867	187	33348	-1210	45310	-1003	15853	86557	79588
ITG1 Sicilia	103	1799	112	3654	-60	3077	-69	1493	5225	46209
ITG2 Sardegna	1034	9825	1210	43725	-838	65373	-1324	13158	137443	258212
RO02 Sud-Est	4855	8533	270	59218	181	n.a.	n.a.	212170	n.a.	123356
SI00 Slovenija	27	222	16	65	-5	n.a.	n.a.	326	n.a.	7039

Table 4.6 Physical aggregates from land and ecosystem accounts – total values by NUTS2

The absolute values of the indicators can be presented by grid cells. An example is presented below for LNEP and Change 1990-2000 in LNEP. This presentation shows up the spatial distribution of the indicator.

In that sense, a gateway between the meso and micro scales is established. Of course, not all details are given in each grid cell, an aggregate instead. But this grid-cell aggregate has a meaning for the local actors:

- it allows comparing the local situation to its environment;
- it helps in comparing any local case with similar cases elsewhere in Europe;

- the change has a strong overall meaning, would it be the pressure from the neighbourhood (so-called temperature) or the resulting state summarised by LNEP.

And of course, these aggregates are meaningful for framing policies and assessing their implementation.

The maps below, where an overlay of socio-ecosystem wetlands boundaries has been made show clearly important differences in Socio-Ecological Systems (SES) ecological potential, resulting in particular from the importance of rice fields. The evolution of the indicator indicates an important intensification of land use in SES in Spain, less in France.

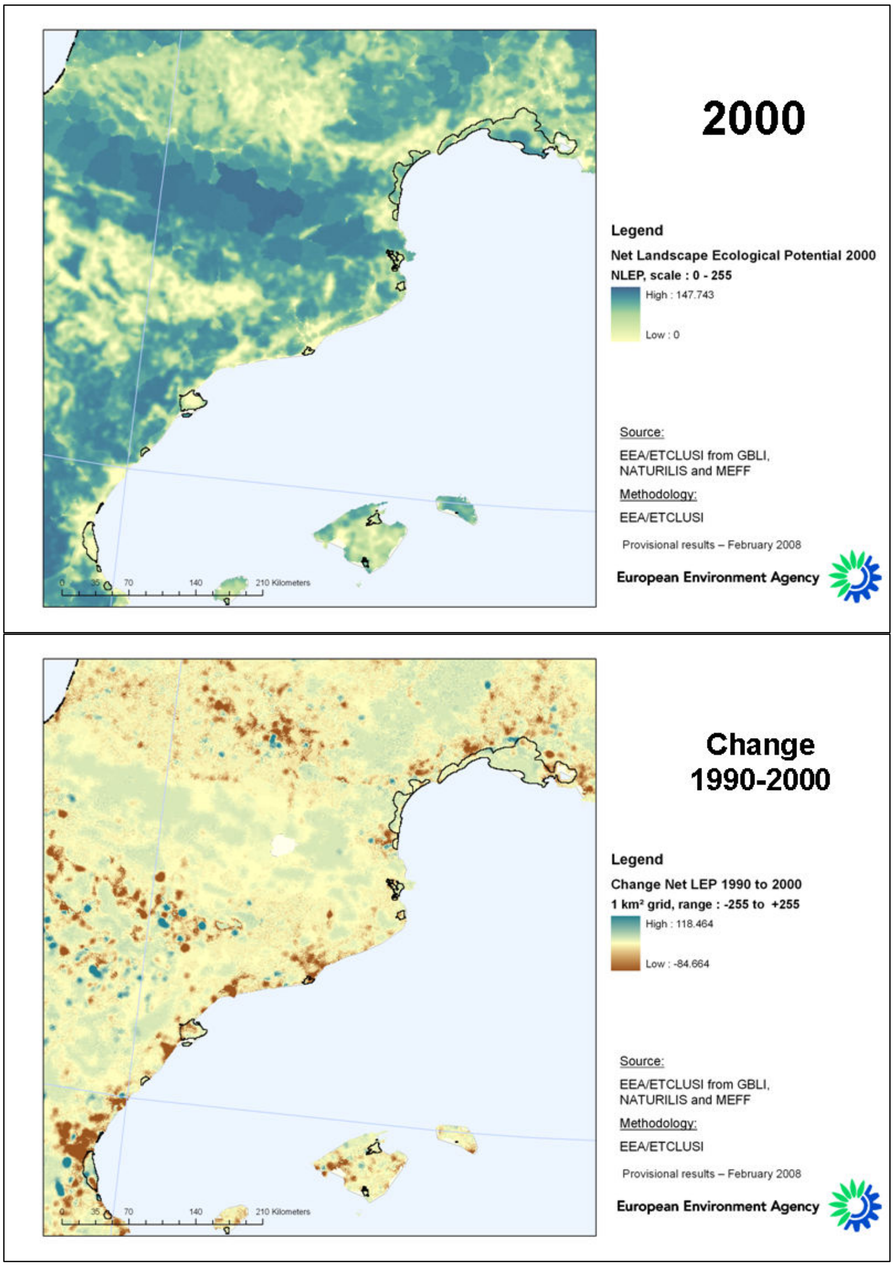


Figure 4.1 Landscape Ecological Potential 2000 and change 1990-2000 – North West Mediterranean – overlay of socio-ecosystem wetlands boundaries.

LEAC Aggregates - Coastal Wetlands Socio-Ecological Systems (SES)

		MEAN VALUES PER KM² IN SES								
	Surface of coastal SES Wetlands	Urban temperature 2000	Change in Urban temperature 1990-2000	Intensive Agriculture Temperature 2000	Change in Intensive Agriculture temperature 1990-2000	Landscape Net Ecological Potential 2000	Change in Landscape Net Ecological Potential 1990-2000	Nature designation index (combined N2000 & national)	Mean Effective Mesh Size in SES 2005	Population Density (inhab/km²) 2000
UNITS	km²	0-100	0-100	0-100	0-100	0-100	0-100	0-100	logN(MEFF)	inhabitants
Coastal Regions with SES Wetlands	SURF_SES_WET1	URB_TEMP_2	URB_TEMP_9	XB_TEMP_20	XB_TEMP_90	LNEP2000	LNEP_90_00	NATURILIS_	LNMEFF	POPCLC_200
BG13 Severoiztochen	17	6	0.1	62	0.2	n.a.	n.a.	24	n.a.	25
BG23 Yugoiztochen	175	12	0.1	35	0.0	n.a.	n.a.	16	n.a.	267
CS Montenegro	452	1	n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ES51 Cataluña	695	8	1.0	60	-0.2	46	-2	8	122	112
ES52 Comunidad Valenciana	898	9	3.7	50	-1.1	56	-3	20	111	404
ES53 Illes Balears	203	4	1.1	42	-1.3	60	-1	20	104	115
ES61 Andalucía	3444	4	0.4	47	2.5	74	-6	17	163	188
ES62 Región de Murcia	622	6	1.6	55	-0.7	30	-1	15	92	145
FR81 Languedoc-Roussillon	1636	8	0.2	30	0.7	75	-2	31	112	140
FR82 Provence-Alpes-Côte d'Azur	1601	7	0.2	22	0.7	83	-2	35	121	154
FR83 Corse	195	6	0.1	25	-0.5	72	-1	11	107	44
GR11 Anatoliki Makedonia, Thraki	1154	2	n.a.	60	n.a.	n.a.	n.a.	23	n.a.	32
GR12 Kentriki Makedonia	1343	4	n.a.	77	n.a.	n.a.	n.a.	11	n.a.	75
GR14 Thessalia	51	5	n.a.	50	n.a.	n.a.	n.a.	12	n.a.	57
GR21 Ipeiros	442	2	n.a.	21	n.a.	n.a.	n.a.	29	n.a.	40
GR22 Ionia Nisia	67	7	n.a.	20	n.a.	n.a.	n.a.	14	n.a.	232
GR23 Dytiki Ellada	956	2	n.a.	41	n.a.	n.a.	n.a.	25	n.a.	44
GR24 Sterea Ellada	172	2	n.a.	60	n.a.	n.a.	n.a.	35	n.a.	82
GR25 Peloponnisos	138	4	n.a.	38	n.a.	n.a.	n.a.	10	n.a.	92
GR41 Voreio Aigaio	105	1	n.a.	43	n.a.	n.a.	n.a.	29	n.a.	21
GR42 Notio Aigaio	12	2	n.a.	7	n.a.	n.a.	n.a.	8	n.a.	44
HR Croatia	254	3	n.a.	9	n.a.	n.a.	n.a.	0	n.a.	108
ITD3 Veneto	1416	5	0.2	32	0.1	86	-2	24	147	180
ITD4 Friuli-Venezia Giulia	335	4	0.1	37	2.0	83	-2	25	147	78
ITD5 Emilia-Romagna	917	4	0.2	65	-0.1	47	-3	17	141	93
ITE1 Toscana	345	7	-0.3	27	0.6	75	-2	34	115	131
ITF4 Puglia	673	3	0.3	50	-1.8	67	-1	24	129	118
ITG1 Sicilia	103	17	1.1	35	-0.6	30	-1	14	51	449
ITG2 Sardegna	1034	10	1.2	42	-0.8	63	-1	13	133	250
RO02 Sud-Est	4855	2	0.1	12	0.0	n.a.	n.a.	44	n.a.	25
SI00 Slovenija	27	8	0.6	2	-0.2	n.a.	n.a.	12	n.a.	261

Table 4.7 Physical aggregates from land and ecosystem accounts – Mean values by NUTS2

Table 4.7 compares the mean values of the indicator (as Total Value/ SES surface) in NUTS2. The slow degradation of the ecological potential due to SES wetlands is general. The results of Table 4.7 are illustrated by the following maps:

- Figure 4.2 Mean Pressure/Temperature from Intensive Agriculture over SES Wetlands, 2000 and Change 1990-2000
- Figure 4.3 Mean Pressure/Temperature from Urban land use over SES Wetlands, 2000 and Change 1990-2000
- Figure 4.4 Population density in SES Wetlands

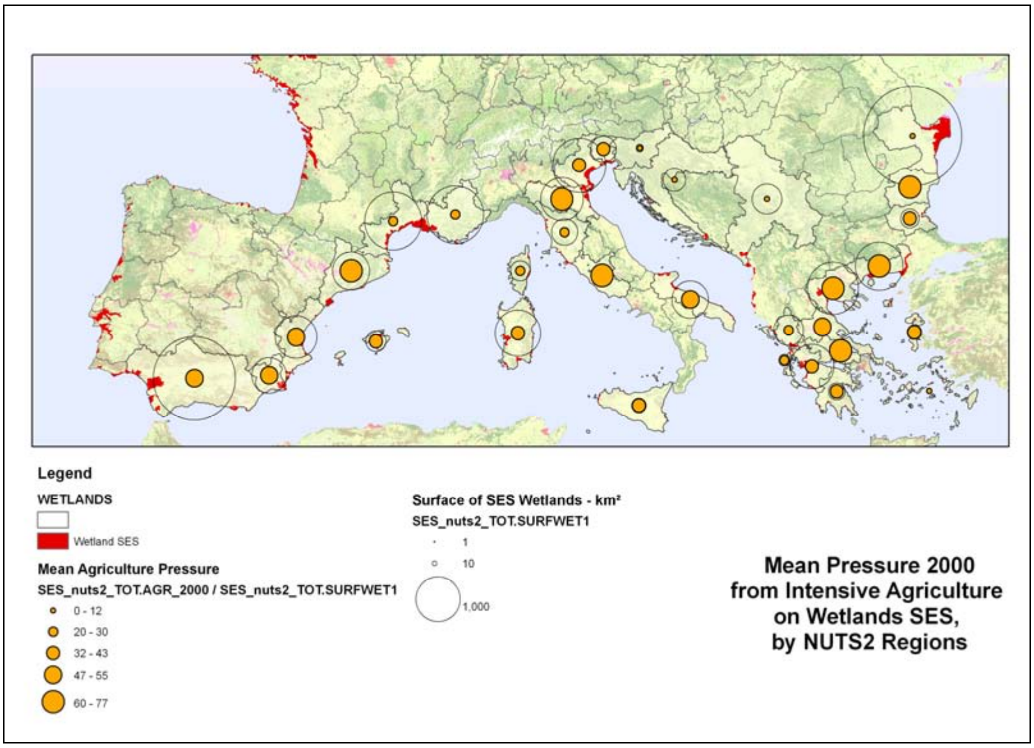


Figure 4.2 Mean Pressure/Temperature from Intensive Agriculture over Wetlands, by NUTS2, 2000

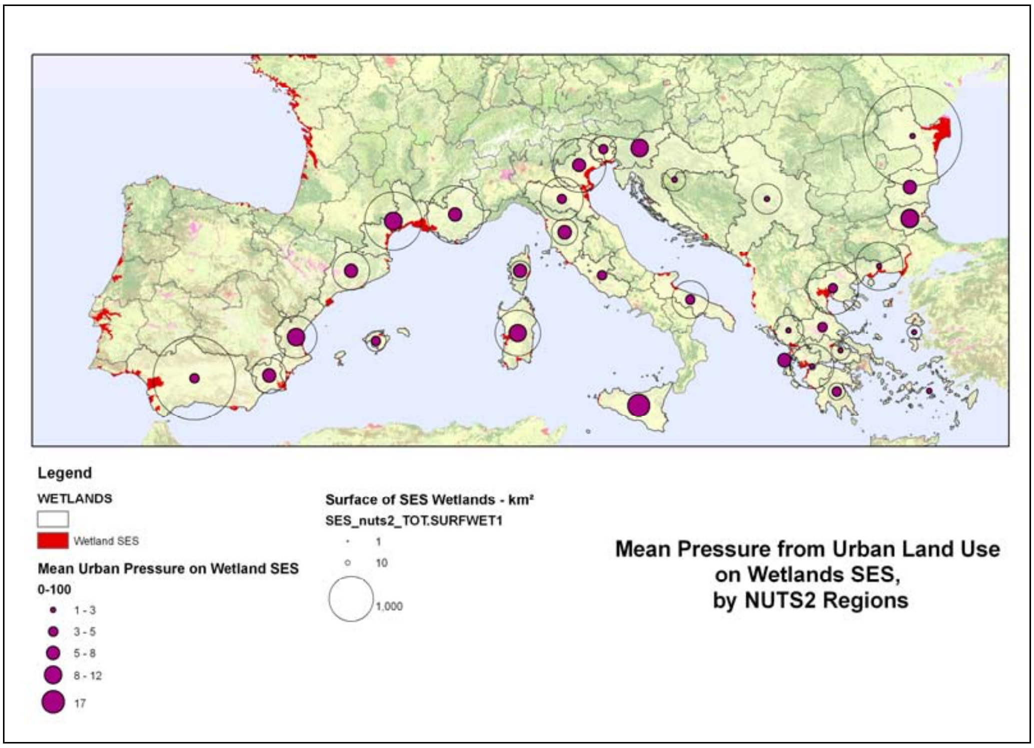


Figure 4.3 Mean Pressure/Temperature from Urban land use over SES Wetlands, by NUTS2, 2000

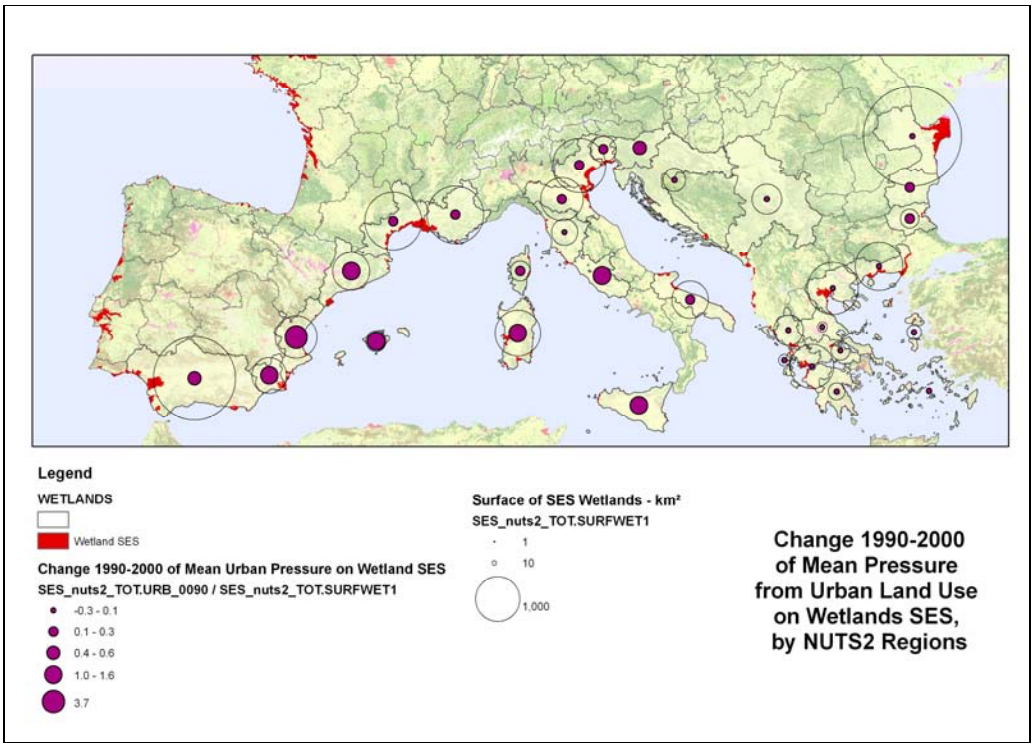


Figure 4.4 Change 1990-2000 of Mean Pressure/Temperature from Urban land use over SES Wetlands, by NUTS2

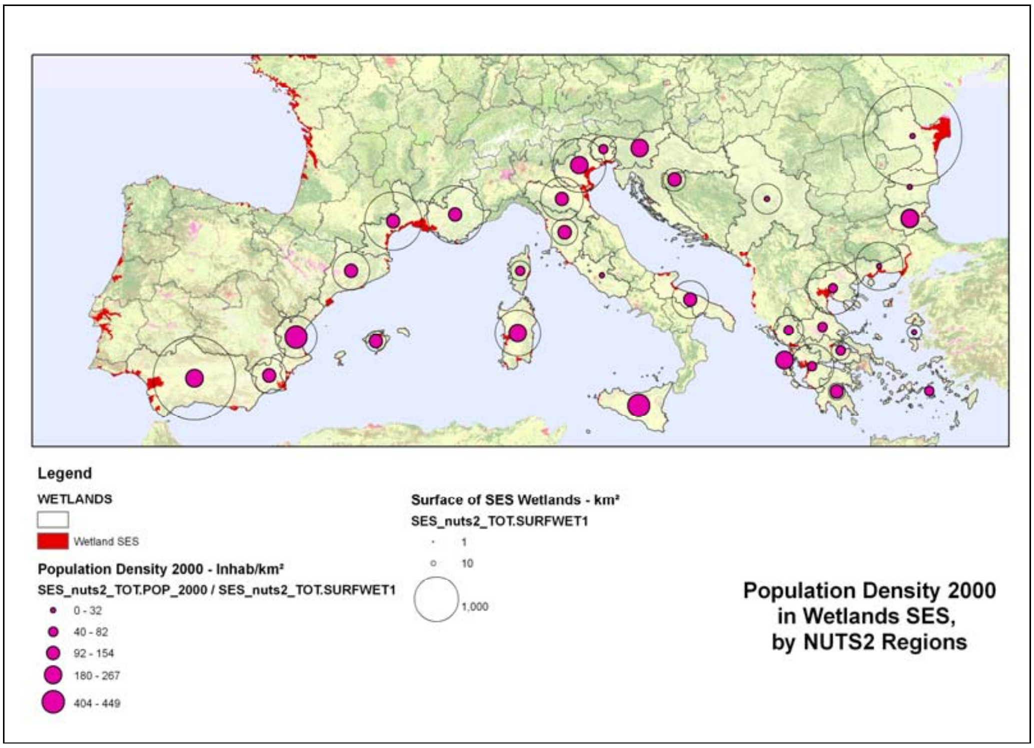


Figure 4.5 Population densities within SES Wetlands, by NUTS2-2000

Comments: increase of intensive agriculture and urban “temperatures” (combined pressure within the wetland systems and in their neighbourhood) – in particular in West Mediterranean.
[…]

4.5. Further accounting for ecosystem health/resilience at the Mediterranean meso scale

- Landscape micro and linear features, ecotones
- Resilience of species communities: specialism index, biodiversity intactness
- NPP and HANPP

Physical accounts as a basis for computing maintenance and restoration costs […]

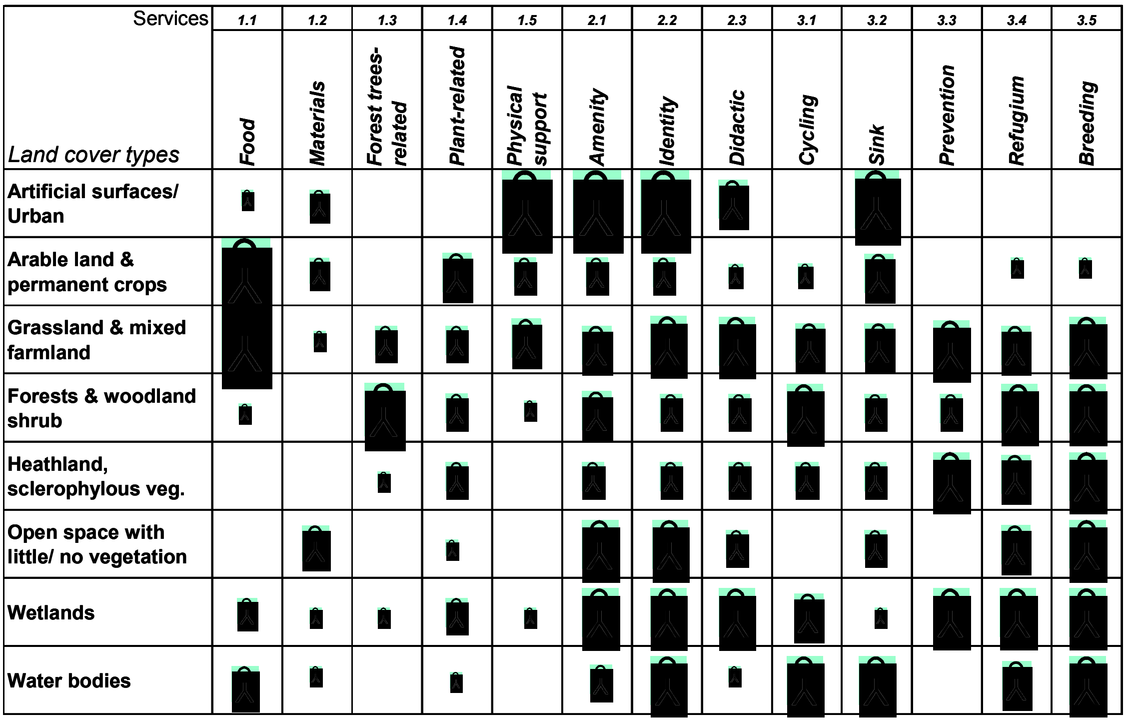
4.6. Land cover, land use and practical assessment of ecosystem services

Biodiversity supports ecosystem resilience ecosystem functioning and therefore possible services

The assessment should distinguish between ecosystem services according to their dependence from biodiversity:

- Closely dependent (products of family agriculture, picking plants, some recreation and regulation services)
- Dependent on a longer term (e.g. intensive agriculture or forestry, fish farming)
- Not directly dependent from biodiversity (e.g. extraction of salt in wetlands)

Services are services to people, of given socio-economic groups, somewhere. Measuring ecosystem services in physical steps leads to produce this kind of matrix (or tensor, a more than 2 dimensions matrix).



This spatial and multidisciplinary approach is necessary in order to streamline the issue of "benefits transfers" from particular local case studies to overall assessments. This is a step necessary for avoiding double counting of services and for giving more credibility to shadow pricing […].

Chapter 5. Selected case studies

5.1. Introduction

Four wetlands have been selected as case studies for this report: Doñana in Spain, Camargue in France, Amvrakikos in Greece and the Danube Delta in Romania.

The criteria for such a selection were based firstly on the regional relevance of each sites and their importance in the Mediterranean and European context and secondly on the knowledge accumulated in each site and relatively easy to access. The existence of a conservation authority in charge of managing the sites has been another consideration, having in view the practical use of the accounts. Another criteria was at this stage the belonging to the Corine area in order to test the feasibility and relevance of nested multi-scale accounts.

The standard gridded accounts can be established at the site level. The summary table of the indicators derived from land and ecosystem accounts gives a first hint of the situation; it allows comparisons between sites as well as of the relative position of the site in various geographical breakdowns: 10 km coastal strip, administrative regions, sub-river basins…

		Units	AMVRAKIKOS GREECE	CAMARGUE FRANCE	DANUBE DELTA ROMANIA	DONANA SPAIN
Surface of coastal SES Wetlands		km²	1802	827	5858	1473
TOTAL VALUES IN SES	Urban temperature 2000	0-100	2879	268	7411	739
	Change in Urban temperature 1990-2000	0-100	0	14	194	74
	Intensive Agriculture Temperature 2000	0-100	28538	20701	69049	19690
	Change in Intensive Agriculture temperature 1990-2000	0-100	182	814	1295	995
	Landscape Net Ecological Potential 2000	0-100	n.a	83228	n.a	180982
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a	-1513	n.a	-4098
	Nature designation index (combined N2000 & national)	0-100	38696	79452	531461	117894
	Effective Mesh Size 2005	logN(MEFF)	n.a	124672	n.a	278560
	Population 2000	inhabitants	104357	21917	43702	11023
MEAN VALUES PER KM² IN SES	Urban temperature 2000	0-100	1.60	0.32	1.27	0.50
	Change in Urban temperature 1990-2000	0-100	0.00	0.02	0.03	0.05
	Intensive Agriculture Temperature 2000	0-100	15.84	25.03	11.79	13.37
	Change in Intensive Agriculture temperature 1990-2000	0-100	0.10	0.98	0.22	0.68
	Landscape Net Ecological Potential 2000	0-100	n.a	100.64	n.a	122.87
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a	-1.83	n.a	-2.78
	Nature designation index (combined N2000 & national)	0-100	21.47	96.07	90.72	80.04
	Mean Effective Mesh Size in SES 2005	logN(MEFF)	n.a	150.75	n.a	189.11
	Population Density (inhab/km²) 2000	inhabitants	58	27	7	7

Danube delta is the largest delta in Europe with a very long history of relations of mankind to nature. It brings as well the Black Sea wetlands into the whole picture which is named sometimes Pan-Mediterranean.. Camargue is a very well known site, of national and international interest. It is the biggest delta in the western Mediterranean part where rather intensive economic activities coexist with nature via hydraulic management. Doñana has a clear western Mediterranean character even though it is on the Atlantic façade. Amvrakikos in Greece represents in the eastern Mediterranean and, being structured around a gulf it presents accurately the particular relation of wetlands to the sea.

5.2. Amvrakikos case study

Preamble: Amvrakikos seen from Europe or the LEAC story

Land cover accounts can give a first useful picture of Amvrakikos and its recent evolution. This picture presents the park in its (land cover) environment and offers gateways to the broad European picture as well as to other sites with which comparisons are fruitful. These accounts being based on a grid (on the following maps, a 1 km2 gird is used) they are an efficient framework for integrating socio-economic statistics and ecological monitoring data.

First, the Corine map:

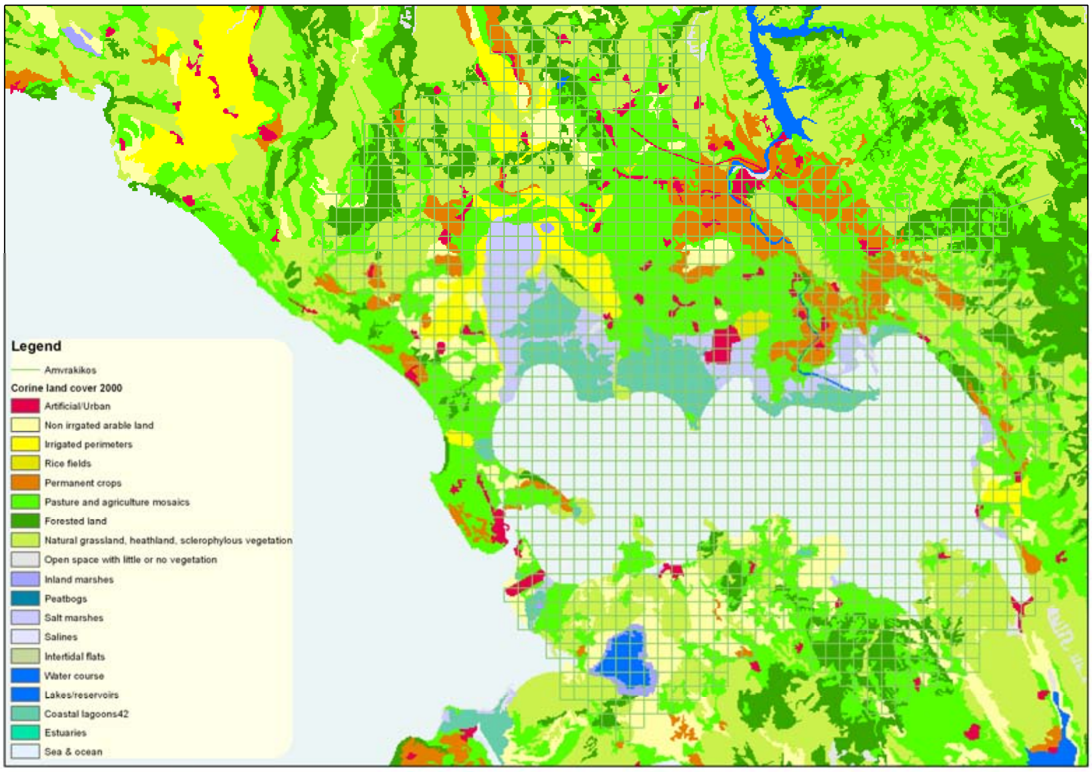


Figure 5.2.1 Amvrakikos land cover; CLC2000

The same tables as produced for the whole Mediterranean basin can be established for the site. They tell about:

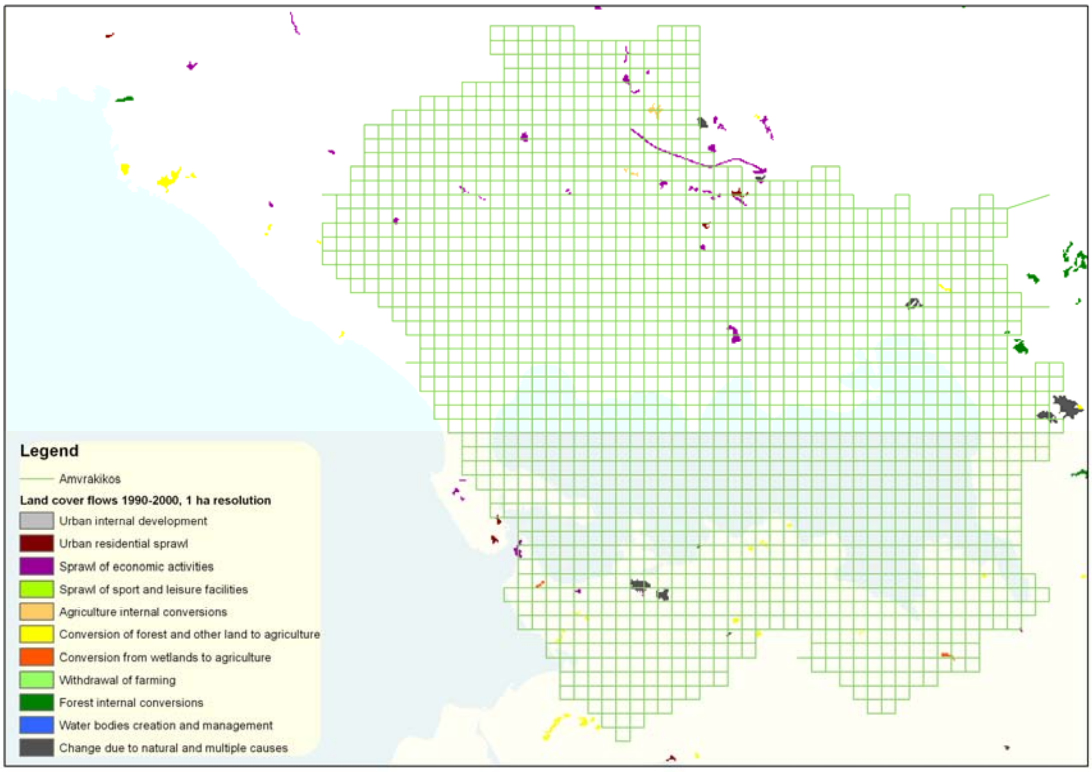
Land cover

		Amvrakikos		
		1990	2000	Net change
111	Continuous urban fabric			0
112	Discontinuous urban fabric	2309	2371	62
121	Industrial or commercial units	570	788	218
122	Road and rail networks and associated land			0
123	Port areas			0
124	Airports	214	214	0
131	Mineral extraction sites	115	138	23
132	Dump sites			0
133	Construction sites	3	126	123
141	Green urban areas			0
142	Sport and leisure facilities	35	35	0
211	Non-irrigated arable land	12236	12288	52
212	Permanently irrigated land	5713	5700	-13
213	Rice fields	406	396	-10
221	Vineyards			0
222	Fruit trees and berry plantations	6645	6533	-112
223	Olive groves	4115	4130	15
231	Pastures	98	98	0
241	Annual crops associated with permanent crops			0
242	Complex cultivation patterns	27753	27535	-218
243	Agriculture mosaics with natural vegetation	14995	15095	100
244	Agro-forestry areas			0
311	Broad-leaved forest	4792	4765	-27
312	Coniferous forest	213	209	-4
313	Mixed forest	807	807	0
321	Natural grassland	11342	11278	-64
322	Moors and heathland			0
323	Sclerophyllous vegetation	21594	21688	94
324	Transitional woodland shrub	7325	7342	17
331	Beaches, dunes and sand plains	222	274	52
332	Bare rock			0
333	Sparsely vegetated areas	309	309	0
334	Burnt areas	188		-188
335	Glaciers and perpetual snow			0
411	Inland marshes	675	672	-3
412	Peatbogs			0
421	Salt marshes	6873	6808	-65
422	Salines	120	120	0
423	Intertidal flats			0
511	Water courses	366	298	-68
512	Water bodies (lakes & reservoirs)	1000	1016	16
521	Coastal lagoons	7329	7329	0
522	Estuaries			0
523	Sea and ocean			0
	TOTAL	**138362**	**138362**	**0**

Land cover flows 1990-2000

		Amvrakikos
		Flows 1990-2000
lcf12	*Recycling of developed urban land*	
lcf21	*Urban dense residential sprawl*	
lcf22	*Urban diffuse residential sprawl*	62
lcf31	*Sprawl of industrial & commercial sites*	218
lcf35	*Sprawl of mines and quarrying areas*	115
lcf37	*Construction*	123
lcf38	*Sprawl of sport and leisure facilities*	
lcf412	*Diffuse extension of set aside fallow land and pasture*	9
lcf421	*Conversion from arable land to permanent irrigation perimeters*	
lcf422	*Other internal conversions of arable land*	
lcf433	*Other conversions between vineyards and orchards*	
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*	
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*	
lcf444	*Diffuse conversion from permanent crops to arable land*	
lcf451	*Conversion from arable land to vineyards and orchards*	
lcf463	*Diffuse conversion from pasture to arable and permanent crops*	52
lcf511	*Intensive conversion from forest to agriculture*	
lcf512	*Diffuse conversion from forest to agriculture*	10
lcf521	*Intensive conversion from semi-natural land to agriculture*	38
lcf522	*Diffuse conversion from semi-natural land to agriculture*	86
lcf53	*Conversion from wetlands to agriculture*	28
lcf54	*Other conversions to agriculture*	
lcf62	*Withdrawal of farming without significant woodland creation*	
lcf71	*Conversion from transitional woodland to forest*	
lcf72	*New forest and woodland creation, afforestation*	
lcf73	*Forests internal conversions*	
lcf74	*Recent fellings, re-plantation and other transition*	22
lcf81	*Water bodies creation*	
lcf91	*Semi-natural creation and rotation*	349
lcf93	*Coastal erosion*	
lcf99	*Other changes and unknown*	65
	No Change	137185
	TOTAL	**138362**

These flows can be mapped as well:



And first **<u>land and ecosystem</u>** physical aggregates:

		Units	AMVRAKIKOS GREECE
Surface of coastal SES Wetlands		km²	1802
TOTAL VALUES IN SES	Urban temperature 2000	0-100	2879
	Change in Urban temperature 1990-2000	0-100	0
	Intensive Agriculture Temperature 2000	0-100	28538
	Change in Intensive Agriculture temperature 1990-2000	0-100	182
	Landscape Net Ecological Potential 2000	0-100	n.a
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a
	Nature designation index (combined N2000 & national)	0-100	38696
	Effective Mesh Size 2005	logN(MEFF)	n.a
	Population 2000	inhabitants	104357
MEAN VALUES PER KM² IN SES	Urban temperature 2000	0-100	1.60
	Change in Urban temperature 1990-2000	0-100	0.00
	Intensive Agriculture Temperature 2000	0-100	15.84
	Change in Intensive Agriculture temperature 1990-2000	0-100	0.10
	Landscape Net Ecological Potential 2000	0-100	n.a
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a
	Nature designation index (combined N2000 & national)	0-100	21.47
	Mean Effective Mesh Size in SES 2005	logN(MEFF)	n.a
	Population Density (inhab/km²) 2000	inhabitants	58

Introduction

Amvrakikos Gulf is an enclosure of the Mediterranean sea, on the western coast of Greece. On the Gulf `s northern coast, the rivers Louros and Arachtos form a double delta with extensive fresh water marshes, salt marshes and lagoons. These wetlands in Amvrakikos are one of the largest wetland areas in Mediterranean Europe, characterized by very diverse wetland habitat types.

The marine waters of Amvrakikos are a major fishing ground for commercial coastal fisheries, as well as an area of aquaculture development, where fish are grown in fish cages.

So interesting question rises on what are the environmental conditions like in the Amvrakikos area, which are the functions of this complex ecosystem and how they are affecting the ecosystem services provided to mankind. Most importantly how much it costs to maintain and restore the ecosystems that provide such services.

5.2.1. The profile of the Amvrakikos National Park

The Amvrakikos National Park is a complex site of a total of 1800 km² area consisting of the marine waters of the Amvrakikos Gulf (approx. 400 km²) and the adjacent coastal lagoons, salt marshes and freshwater marshes, hills and remnants of riverine forests (approx. 10.000 ha) and buffer zones with agricultural land and villages.

The Socio Ecological System (SES) of the Amvrakikos National Park is considered as the total area related to the municipalities that are stake holders of the Park (approx. 100,000 ha of land) and 35,000 ha of sea. The terrestrial component comprises of 20 municipalities from the prefecture of Arta with 39,000 inhabitants / 31430 ha and 11 municipalities from the Prefecture of Preveza with 23,000 inhabitants/ 18570 ha in the north and 6 municipalities from the Prefecture of Aetoloakarnania with 15,500 inhabitants/ 54690 ha in the east and south part of the Gulf (data from 1991). All socioeconomic data are calculated for the SES area.

The Amvrakikos water catchment area is defined geographically and it occupies approximately three times as big an area than the terrestrial SES (aprox. 300,000ha). This area is used for water balance calculations.

Characteristics	Description
Location	Region of Ipiros and Region of Dytiki Ellada, western Greece
Spatial extent	Marine / the Amvrakikos gulf Wetlands/ Riparian forests
Biophysical system of reference	Amvrakikos water catchment area
Municipalities	20 municipalities from the prefecture of Arta with 39,000 inhabitants / 31430 ha 11 municipalities from the Prefecture of Preveza with 23,000 inhabitants/ 18570 ha 6 municipalities from the Prefecture of Aetoloakarnania with 15,500 inhabitants/54690 ha Total socioeconomic area is about 100,000 ha of land and 350,000 ha of sea
Human population	77.500 (1991)
Natural protected areas	Amvrakikos National Park, Ramsar Site, Natura 2000 site,SPA and SCI site
Wetland ecosystems	Louros and Arachthos rivers delta, Other coastal lagoons
Main ecosystem services	Agriculture, Cattle farming, Fisheries, Clean water, Flood prevention, sedimentary balance, refuge for wildlife species
Other ecosystem services	tourism, research, environmental education, nutrient cycling
Characterization of economic system	Primary sector dominance
Characterization of political and administrative institutions	Local: Amvrakikos National Park management Authority with stakeholders management Board established by the Ministry of the Environment Prefectures: 3 (Arta, Preveza, Aetoloakarnania Regions 2. Ipiros (Arta and Preveza), Dytiki Ellada (Aetoloakarnania). International: European Union, United nations
Environmental problems and disturbances	Dead fish incidents in the lagoons and marine fish cultures; Lack of freshwater input to the lagoons and the sea; Detection of contamination in molluscs; River water pollution incidents; Algae blooms in the lagoons; Changes of wetland vegetation patterns; Decreased population of endangered bird species.
Methodology used in this work	Maps statistical data and other published data by the Ministry of Environment, Life Nature project application and final report

Table 1: Profile of Amvrakikos Socio-Ecological System

Wetland habitats, water regime and species diversity

Three of the largest natural lagoons in Greece dominate the site: Rodia and Tsoukalio Lagoons (ca. 32 km^2) and Logarou Lagoon (ca. 28 km^2). Extensive areas of salt marsh, reed beds and brackish water meadows border the lagoons. Rodia Marsh is one of the largest reed marshes in SE Europe (covering ca. 27 km2). The Louros and Arachtos rivers also retain small remnants of riparian forest (ca. 5 km^2). Beside lagoons, most important and extensive habitat types are the halophytic communities of *Arthrocnemetalia* and wet meadows with *Juncus.* There are steep limestone hills adjacent to the wetlands and one of them, Mavrovouni hill (ca. 6.5 km^2, 329 m. elevation), located near the centre of the wetland area, still supports relic stands of oak.

Due to the geomorphologic characteristics of the area and numerous human interventions in the past, since the last 20 years at least, the lagoons and the riparian vegetation receive freshwater mainly by precipitation. Flooding of the Louros River has ceased and its flow is directed to the sea, regulated by an irrigation dam, which today has a continuous flow due to its serious siltation. The mean annual discharge below the dam is 468 x $10^6 m^3$/year (1957-1995). Flooding of the Arachthos river has also ceased and its flow is directed to the sea, regulated by a hydroelectric/irrigation dam. The mean annual flow below this dam during the years 1982-1995 was 1390x10^6 m^3/ year. The quality of the river water is within standards for aqua-culture and bathing waters. Increased salinity with seasonal variations has been observed in the lagoons.

Several commercial fish species (*Anguilla anguilla, Mugil spp., Solea spp. Gobius niger, Sparus aurata, Dicentraurchus labrax*) are exploited traditionally in the lagoons, which they enter seasonally through openings to the sea.

The whole site supports significant waterfowl populations every winter (100,000 mean, 170,000 max.). The lagoons are estimated to comprise important foraging habitat for 40 of the 78 Annex I bird species present in the site. Salt marshes are very important foraging/ breeding habitats for 47 of them, freshwater marshes and meadows are important for 56 of them (including nationally important colonies of *Platalea leucorodia* -35 pairs, *Plegadis falcinellus* -20 pairs, *Ardea purpurea* -20 pairs), remnants of riparian forests are important for 31 of the Annex I bird species and the oak woods for 4 of them.

5.2.2. History of the site

Three “snapshots” of the state of the site are examined in the present study in the form of ecosystem accounts and ecosystem services. The first one is based on the 1985 study “Amvrakikos gulf, development and environment protection”, coordinated by Thymio Papayiannis and associates for the Ministry of Physical Planning, Housing and the Environment and the Commission of European Communities.

In **1990** the Ramsar site has been delineated and protected since by restrictions on some land uses and human activities. The site however continued to experience rapid deterioration of its essential ecological features, due to mismanagement.

The second snapshot is based on the **1997** study “Environmental issues and management system of the Amvrakikos protected area”, elaborated by Vavizos, Zannaki , Zafeiropoulos and Associates, for the Ministry of Environment , Physical Planning and Public Works.

Between **1998** and **2003** further conservation actions, co-financed by the Life /Nature instrument of the European Commission and the Region of Epirus, were aimed at maintaining the nature conservation value of the area, now a site of the Natura 2000 network. These actions focused on restoring the conservation status of the lagoons and other habitat types which provide critical habitat for 6 priority bird species and the conservation of the loggerhead sea turtle, a priority species in the marine environment.

The final report of this Life Nature project, elaborated by ETANAM SA and OIKOS Nature Management Ltd in **2003** provides the last of the three snapshots of this site, focusing mainly on the Louros basin.

In 2007 the site was declared a National Park and its Management Authority was established by the Hellenic Ministry of Environment.

5.2.3. The water accounts

1985

Water requirements and water balance in the whole of the Amvrakikos catchment area were calculated on the basis of a total 2784.9 m^3x10^6 of water available per year from the two rivers as follows

Drinking water requirements	**YEAR**	Irrigation water requirements	Tourism development requirements	Industry requirements	TOTAL	**Annual water balance calculations**
(166.000 inhabitants) 10,9 m *3X10*6	**1981**					
(168.000 inhabitants) 11,7 m^3x10^6	**1984**	129,5 m^3x10^6	0,1	4,3	145,9	2784,9 -145,9 = +2639,0
(180.000 inhabitants) 22,4 m^3x10^6	**Projection 2000**	244,5 m^3x10^6	0,3	9,9	277,7	2784,8 – 277,7 = + 2507,1

The conclusion of the 1985 study was that the water basin has adequate water resources to support hydroelectric energy production, irrigation of agricultural land and fisheries. However, concerns were put forward for potential pollution from further increase of irrigated agriculture land and for the impact of decreases of freshwater input into the fisheries in the lagoons and the sea.

1997

Water calculations were revised with the 1997 study, taking into account a few very dry years between 1984 and 1988. Estimates of the available water were reduced to 1980 m^3x10^6 annually. The total needs for water for irrigation, drinking water and industry were recalculated to a total annual 448 m^3x10^6 taking into account all plans for extension of irrigated land, new livestock and fish farm units as well as further industrial needs, that were approved or submitted for approval from 1983 to 1995. Furthermore the required water flows were calculated for the spring and summer seasons as follows.

April	May	June	July	August	September
4,6 m(3)/sec	27,0	40,5	47,7	37,8	15,1

The overall conclusion on water balance is the same, ie, there is more water available than the estimated needs. As for the freshwater needs of the wetland and sea, a minimal required flow of the rivers during the dry months in their mouth to the sea as 1/3 of the their mean minimal annual flow was calculated. This gives 5,3 m^3/sec for Louros and 6,6 for Arachthos. By taking these into account there was still the conclusion that there is enough water. As for the repeated reports of process of salinisation of the underground water and the surface waters of Louros river during the last kilometers of its flow, the study considered them as a seasonal phenomenon and no impact is calculated.

A finer scale approach

A finer scale approach in the western part of the delta where Louros river which is the main source of freshwater and sediment, is introduced to show the state prior to the water regulation measures implemented by the Life-Nature project.

Louros river is fed almost exclusively from underground water sources along its course as well as from nearby fountains and spring waters. Due to this fact the river has a remarkably stable water diet, with little seasonal fluctuation. The sediment carried by the river is of rather fine nature and has been dispersed by the waves, creating a shallow basin and arrow like sandbanks instead of dynamic delta formations.

The waters of Louros upstream are of course abstracted and used for irrigation purposes, and for fish farms. Finer scale measurements in 1994 allowed calculations of a medium annual flow measured upstream (see table below) as 18,21 m^3/sec. This flow is gradually reduced to 3,91 m^3/sec , which is actually less than the minimal flow calculated in the 1997 study. Furthermore, the construction of a dyke in 1970s prevented the river waters from entering the lagoon, and a dyke led the water directly to the sea.

Louros flow upstream actual in 1994	before it reaches the marsh of Rodia, actual in 1994	Hypothetical mean minimal annual flow at river mouth, ecological flow	Mean annual discharge below the dam (1957-1995) actual
18,21 m^3/sec	3,91 m^3/sec	5,3m^3 /sec	468x10^6 m^3/year

2003

An agreement with local users allowed the preparations for establishing a controlled entrance of freshwater water in the wetland as a pilot project. It was established that the restoration of freshwater input should use all available means, ie direct flow of the surface waters of the river and some drainage channels as well as pumping of underground waters. The actual pilot phase was operated in the summer of 2003 and aimed at maintaining certain salinity levels in the lagoons and marshes by allowing 3.080.000 m^3 to enter the wetland.

A second phase is planned with a 7.000.000 € project proposal for freshwater restoration into the lagoons.

5.2.4. Ecosystem Health

**Ecosystem Health Distress Syndrome (EDS) Diagnostics: see Chapter 1*

1985

The distress symptoms identified were the following:

- Decreased depth of the main entrance of marine waters to the gulf
- Water regulation and damming of both rivers has introduced Hydraulic changes
- Wetland drainage for agricultural development, impact to fisheries and water diet
- Impacts of constructions to prevent flooding/ sudden flooding of Louros due to the hydroelectric dam created shocks to fish stocks in the lagoon
- Changes in the water exchange openings between the lagoons and the sea, drop of fisheries in the lagoons
- Soil erosion in the surrounding hills due to overgrazing and forest fires
- Hunting pressure to wetland species
- Water pollution of underground and surface waters due to sewage, wastes, 100 units of processing and livestock Between 1978 and 1984, there was 14% increase of the factories related to food and other material processing

1997

The distress symptoms identified were the following:

- Changes in water courses and the surface hydrographic network
- Natural habitat loss due to agriculture or technical works
- Not well studied interventions in the lagoons aiming at increasing fish catches
- Hunting and taking from the wild of non commercial species

MAP – loss of wetlands area 1945-1990

A finer scale approach (life nature application, **1998**) in the western part of the site reveals the following distress symptoms:

- Increased salinity and insufficient water circulation within the lagoons of Tsoukalio-Rodia and Logarou have resulted to changes in their habitat structure.
- A drastic reduction of submerged macrophytes has been noted, reaching more than 50% of their original distribution area in Tsoukalio – Rodia lagoons.
- The characteristic mosaic structure of the water grassland and marsh vegetation is being replaced by mono-dominant *Phragmite* reeds, which is poor in species diversity and structural diversity in terms of foraging and breeding resources for most wetland dependent bird species.
- This degradation in marshland structure has contributed to the decline of Greece's largest known breeding population of *Aythya nyroca*. The inappropriate water management of the marsh and the degradation of habitat serial succession is also negatively affects the wintering *Botaurus stellaris* in the site, which is the only Greek site where breeding of the species probably occurs. Habitat degradation and disruption of hydrological regime of this marsh affects also the conservation value of the site as wintering habitat for *Phalacrocorax pygmeus*.
- The local extinction of domestic water buffalo (*Bubalus bubalis*) in the early 70's and the subsequent lack of reed bed management have contributed also to this state which provides poor foraging and nesting habitat for most wetland dependent species.
- The numbers of wintering ducks have shown a declining trend, even though the site still supports internationally important numbers.
- A 10-50% decrease in traditional lagoon fisheries yield has been noted between the years 1980- 1995.
- Non-consistent, sporadic management works for the improvement of traditional lagoon fisheries, such as dredging for water circulation, which lack a solid scientific base, has caused a reduction in wild duck wintering area and in the primary foraging habitat for the *Pelecanus crispus*, *Phalacrocorax pygmaeus* and *Aquila clanga*.
- Many ecologically sensitive parts of the site have been made accessible by dirt roads and dikes and unauthorized actions in such extended areas are difficult to control. Disturbance is a major threat to all bird species mentioned above and site surveillance is not appropriate due to lack of staff and equipment. Disturbance of sensitive breeding sites of the pelican colonies by fishermen, hunters, poachers

and tourists has caused colony displacement, egg destruction, and increased predation during past years.

- The disruption of the hydrological regime is a limiting factor for the conservation and enhancement of the Dalmatian pelican (*Pelecanus crispus*) colony. Furthermore, the erosion of natural islets in the lagoons and the present lack of woody debris and sediments which used to enter the system by flooding of the Louros river and from the natural breaks in the lagoons barrier spits (now re-enforced by dikes) is threatening with rapid decline the nesting habitat of this species. As a result the nesting islets for the Dalmatian pelicans and several other Annex I species (terns, waterfowl, waders etc.) are declining in size and displacing the colonies.

5.2.5. Selected Socio Economic Indicators

Population in SES (based on the 1997 study)

municipalities	1971	1981	1991	71/81	81/91
Arta	36,716	35,556	38,354	-3,18%,	7,87%
Preveza	19,629	21,158	23.141	-1,19	9,37
Aetoloakarnania	16.904	13,449	14,558	- 20,44	8,25
Total	73,249	56500	61500		

Employment

In the period 1988-1991, 70,5 % of the inhabitants worked in the primary sector, 10,3 % in the secondary sector, 19,2% in the tertiary sector

Land use (National Statistical Service, Greece)

year	Agricultural land (ha)	Grazing land	forest	Inner waters	Settlements and other	total
1981	29210	24810	7830	13070	5020	79940
1991	30000	24840	6860	12880	4520	79100

Market values of agricultural and livestock products in 1993

Gross value of plant production	28303713 dr
Gross value of livestock production	16889177 dr
Total	45192890 dr

Marine fisheries yield

YEAR	Total tons, by big boats (more than 20hp)	Total tons, by boats with less than 19 hp	Total Numbers of Fishermen in boats less than 19 hp
83		383	231
84		379	283
85		245	292,
86		389	297
87		501	307
88		422	324
89		429	328
90		581	296
91		332	352
93	4144,0		

Fisheries in inland waters

YEAR	Indicator of change in fisheries yield	Total tons from the water catchment area	Total Numbers of Fishermen in the water catchment area	Indicator of change in numbers of fishermen
83	100		1127	100
84	106		1144	101
85	97	637	1116	99
86	108	423	1200	106
87	82	457	1153	102
88	80	521	1058	94
89	86	500	1097	97
90	112	1050	1200	106
91	83	508	1184	105
…				
93				

Mean Local market PRICES for fisheries

1992 522 dr/kgr, 1993 611dr/kg, 1994 887dr/kg

Lagoon fisheries accounts were seriously challenged for their accuracy, however these are the available data for the Tsoukalio and Rodia lagoons, which present the greatest yields amongst the lagoons.

In tn	1977	78	79	80	81	82	83	93	94	95
Tsoukalio 2880 ha	162,5	179,7	179,7	161,0	159,1	208,0	166,4	74,9	74,1	84,4
Logarou 2,500 ha	146,6	135,0	130,4	159,9	183,2	205,6	188,8	100,3	102,7	139,3

Funding/ Investment

In **2003**, ETANAM, the Life –nature project beneficiary proposed a set of investments for the sustainable development of the area, that when mature enough would be submitted for financing. These investments include combined actions, ie targeting more than one function or service of the ecosystem (e.g. food provisioning, nature conservation, tourism and recreation, research, that can be grouped as :

Category	**actions**	**Preliminary budget €**
projects for improving general infrastructures	dredging of ports, improvement of fishermen stations	**6,660,650.00**
	restoration of hydraulic balance in the gulf and the wetlands	**7,726,122.00**
projects for environmental protection and management	Protection and monitoring of biodiversity	**7,100,000.00**
	Land purchase in strict reserves	**523,000.00**
	restoration of lagoons	**5,248,454.00**
	sewage treatment and translocation of processing units	**41,284,741.00**
	solid waste management	**8,258,958.00**
	agricultural runoffs reduction and management	**8,791,794.00**
projects for enhancing the surroundings of important sites	making sites attractive for visitors	**7,885,793.00**
	promotion of the site for ecotourism and visitor management	**10,923,178.00**
TOTAL		104,402,690.00

Some of these proposals are already included in the Operational Programme for the environment 2007-2013 of the Ministry of Environment (see next table)

Table 5. Summary of the most important conservation, research and restoration budget invested in Amvrakikos

		Investment expenditure €	**Years**	**Source**
Conservation	**Life –nature project (For the northern coastal part)**	**1,945,400.00**	**1999-2003**	**Life –nature project application to European Commission**
	Protection and monitoring of biodiversity (Total of operations of the National Park management Authority)	**1,024,400.00**	**2007-2013**	**Ministry of Environment, Operational Programme for the Environment**
Research	**Hydraulic works for pollution and sedimentation control**	**410,000.00**	**2007-2013**	**Ministry of Environment, Operational Programme for the Environment**
	Fresh water input and restoration management in the lagoons	**7,000,000.00**		**Final report of Life-nature project (already submitted for financing)**
Maintenance and restoration costs of natural resource	**Removal of dead fish**	**340,000.00**	**2008**	**Press reports**

5.2.6. Two stories as a conclusion

How not to calculate a water balance

In the Amvrakikos water catchment area water balance has been calculated and published twice (1985 and 1997). The studies were commissioned by the Ministry of Environment. In the 1985 calculations the water requirements for drinking water, irrigation, industry and tourism were simply added up and subtracted from the calculated total annual river water quantities. Since the result was positive, there was a conclusion that there is adequate water for the ecosystem functions. In the 1997 calculations, a hypothetical minimal water flow equaling 1/3 of the two rivers mean minimal annual flow was calculated and added to the requirements, which still presented a positive result when subtracted from the calculated available water quantities. There was no attempt to calculate the water requirements for the ecosystem functions.

In reality however, the 1994 measurements have shown that the water reaching the river mouth to the sea were lower than these hypothetical minimal requirements for some parts of the year. It was also shown that only one sixth of the initial mean river water quantity of the river Louros would end up to the sea, which is a change of a rather important magnitude. The impact of such change gradually building up over the years since 1970 was demonstrated in 1998 when several facts were correlated, including loss of lagoon habitat diversity due to increased salinity, decrease of lagoon fisheries production, decrease in numbers of certain bird species.

On 27 February 2008, between 500 and 700 tons of fish were reported dead, in the fish cages of three of the ten existing fish/culture units in the marine waters of Amvrakikos. The total annual yield of these ten fish farms is 1.100 tons. Scientists have suggested that the fish died of anoxic conditions due to sudden water stratification in combination with cold temperatures. The amount of 350.000 € has been spent so far just to remove the dead fish from the sea, and it is most likely that these 3 fish farms will not generate any income for this year. It may well be proven that the reduction of freshwater inflow into the gulf is related to the incidents of these massive deaths of fish in the marine waters of the Gulf occurring today.

The cost of actions proposed to restore some of the ecosystem functions related to freshwater in the lagoons is estimated to 7.000.000,00 € and the investment needed to restore some of these functions in the marine waters of the Gulf is estimated to 1,233,000.000€

Of buffalos and birds: Reintroducing buffalos for restoring habitats and their functions

Herds of water buffalos were historically known to be grazing freshwater marshes in many Mediterranean wetlands, but they were totally removed from Amvrakikos in the early 70s. This was a result of modernization in livestock breeding systems which used imported and improved cow breeds due to their market benefits. However cows could not withstand the climatic conditions as well as the increased salinity of the wetlands and therefore have been kept in farms, grazing in the hills and adjacent areas.

The extinction of water buffalos in Amvrakikos and the subsequent lack of reed bed management lead to an increase of reed bed habitat within the lagoons, a state which provides poor foraging and nesting habitat for most wetland dependent bird species.

In 2001, 5 water buffaloes were reintroduced in the wetland through a conservation management project co financed by the European. A wooden shed and a freshwater supply ditch were built in an enclosed area of 5 hectares. The existing plant communities and the effect of grazing were recorded by experimental cages which were placed in the enclosed area. Later, a second shed was built (June 2002) and 10 more animals were installed (July 2002) outside the fence so as not to alter the grazing capacity of the enclosed area under study.

Water buffaloes have proved to be a useful restoration and management tool, combined with increased freshwater inflow and circulation into the lagoons. They have also proved to be an important ecotourism attraction to the 3000/ year visitors of the site. Interestingly, the buffaloes have been also providing some marginal revenue to the herd keeper due to the rising markets for buffalo meat and cheese which has less fat than that of the cows and buffalo milk and butter which are used in traditional oriental sweets.

5.3. The Camargue: a Socio-Ecosystem in continuing change

Preamble: The Camargue seen from Europe or the LEAC story
Land cover accounts can give a first useful picture of the Camargue and its recent evolution. Because of the asymmetric data availability, some parts of this report will deal on the Natural Regional Park (NRP) of Camargue, while others will deal with the Camargue larger ecosystem –the paleo Rhône delta. Namely, the following Corine land use analysis is based on the NRP of Camargue (present section). The analysis of land use changes between 1942 and 1984 and the species accounts, will be based in the Camargue Rhône delta data (see next section).

Therefore, the following picture presents the Camargue Natural Regional Park (the area within the green grid) in its (land cover) environment and offers gateways to the broad European picture as well as to other sites with which comparisons are fruitful. These accounts being based on a grid (on the following maps, a 1 km2 gird is used) they are an efficient framework for integrating socio-economic statistics and ecological monitoring data.
First, the Corine map (the area within the green grid covers the Camargue Natural Regional Park):

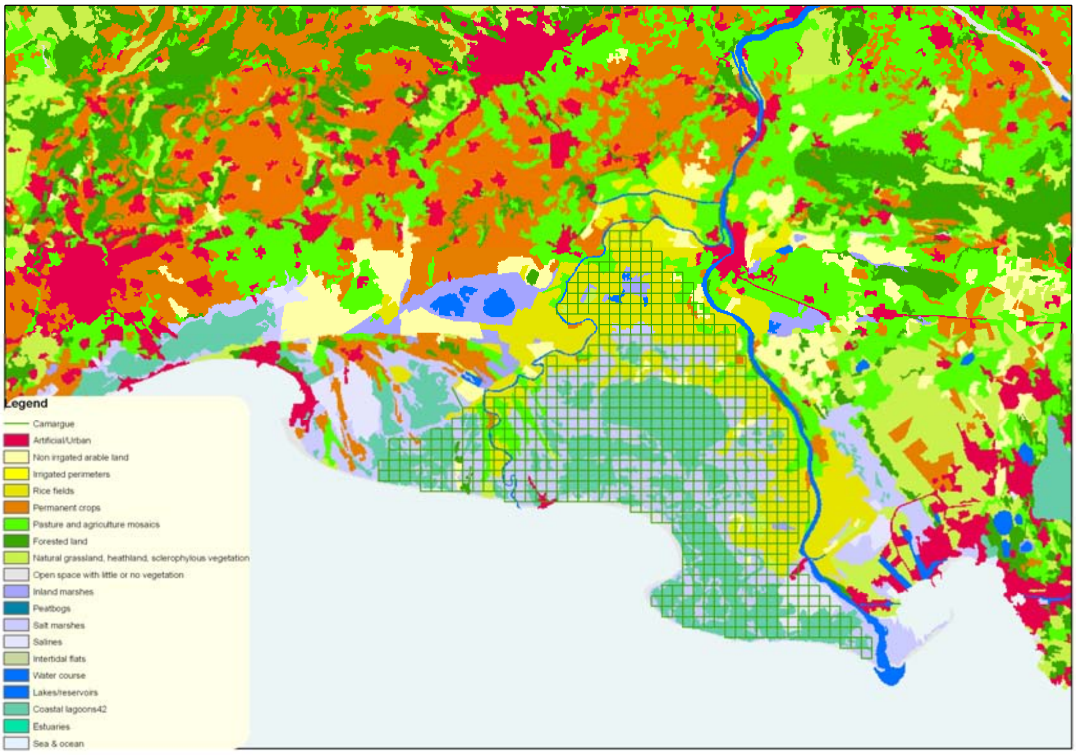


Figure 5.3.1 Camargue land cover; CLC2000

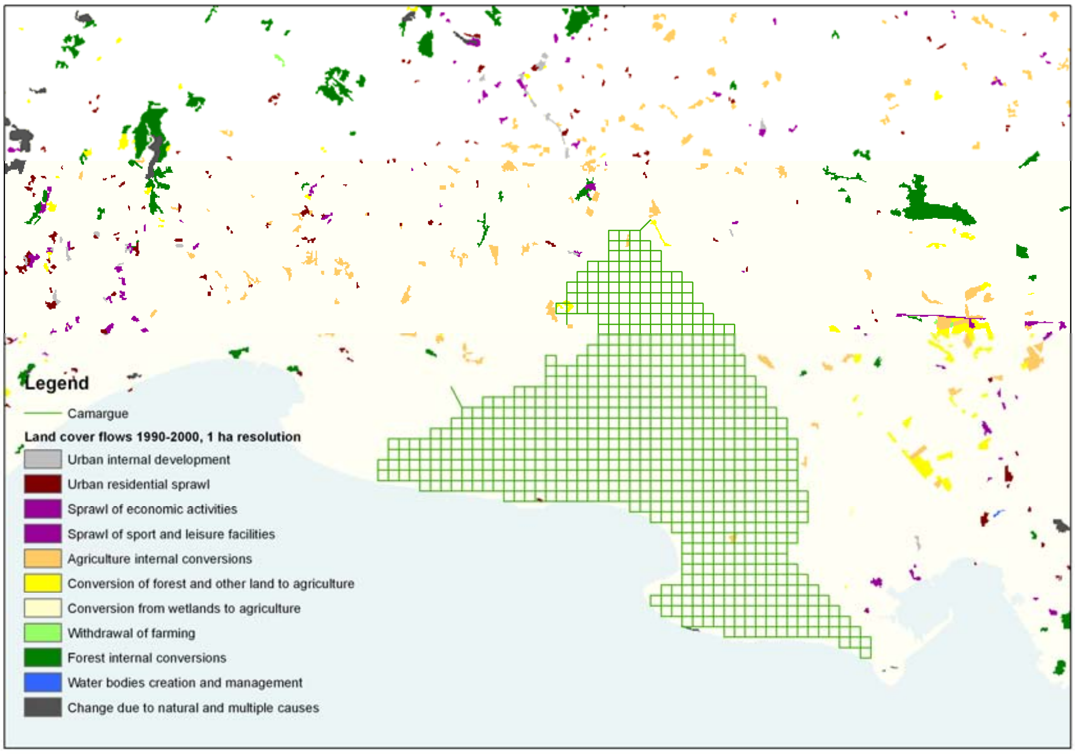
The same tables as produced for the whole Mediterranean basin can be established for the site. They tell about:
Land cover

		Camargue		
		1990	2000	Net change
111	Continuous urban fabric			0
112	Discontinuous urban fabric	226	239	13
121	Industrial or commercial units			0
122	Road and rail networks and associated land			0
123	Port areas			0
124	Airports			0
131	Mineral extraction sites			0
132	Dump sites			0
133	Construction sites	19		-19
141	Green urban areas			0
142	Sport and leisure facilities	26	26	0
211	Non-irrigated arable land	1186	1134	-52
212	Permanently irrigated land			0
213	Rice fields	19925	20174	249
221	Vineyards	208	168	-40
222	Fruit trees and berry plantations	327	311	-16
223	Olive groves			0
231	Pastures			0
241	Annual crops associated with permanent crops			0
242	Complex cultivation patterns	3857	3846	-11
243	Agriculture mosaics with natural vegetation			0
244	Agro-forestry areas			0
311	Broad-leaved forest	24	24	0
312	Coniferous forest	157	157	0
313	Mixed forest			0
321	Natural grassland	1169	1087	-82
322	Moors and heathland			0
323	Sclerophyllous vegetation			0
324	Transitional woodland shrub	38	38	0
331	Beaches, dunes and sand plains	1205	1233	28
332	Bare rock			0
333	Sparsely vegetated areas			0
334	Burnt areas			0
335	Glaciers and perpetual snow			0
411	Inland marshes	703	703	0
412	Peatbogs			0
421	Salt marshes	22929	22900	-29
422	Salines	1750	1750	0
423	Intertidal flats			0
511	Water courses	735	735	0
512	Water bodies (lakes & reservoirs)	178	178	0
521	Coastal lagoons	26700	26687	-13
522	Estuaries			0
523	Sea and ocean	57	29	-28
	TOTAL	**81419**	**81419**	**0**

Land cover flows 1990-2000

		Camargue
		Flows 1990-2000
lcf12	*Recycling of developed urban land*	
lcf21	*Urban dense residential sprawl*	
lcf22	*Urban diffuse residential sprawl*	13
lcf31	*Sprawl of industrial & commercial sites*	
lcf35	*Sprawl of mines and quarrying areas*	
lcf37	*Construction*	
lcf38	*Sprawl of sport and leisure facilities*	
lcf412	*Diffuse extension of set aside fallow land and pasture*	
lcf421	*Conversion from arable land to permanent irrigation perimeters*	52
lcf422	*Other internal conversions of arable land*	
lcf433	*Other conversions between vineyards and orchards*	
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*	61
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*	
lcf444	*Diffuse conversion from permanent crops to arable land*	24
lcf451	*Conversion from arable land to vineyards and orchards*	16
lcf463	*Diffuse conversion from pasture to arable and permanent crops*	35
lcf511	*Intensive conversion from forest to agriculture*	
lcf512	*Diffuse conversion from forest to agriculture*	
lcf521	*Intensive conversion from semi-natural land to agriculture*	82
lcf522	*Diffuse conversion from semi-natural land to agriculture*	
lcf53	*Conversion from wetlands to agriculture*	29
lcf54	*Other conversions to agriculture*	19
lcf62	*Withdrawal of farming without significant woodland creation*	
lcf71	*Conversion from transitional woodland to forest*	
lcf72	*New forest and woodland creation, afforestation*	
lcf73	*Forests internal conversions*	
lcf74	*Recent fellings, re-plantation and other transition*	
lcf81	*Water bodies creation*	
lcf91	*Semi-natural creation and rotation*	
lcf93	*Coastal erosion*	29
lcf99	*Other changes and unknown*	57
	No Change	81002
	TOTAL	**81419**

These land cover flows can be mapped as well:

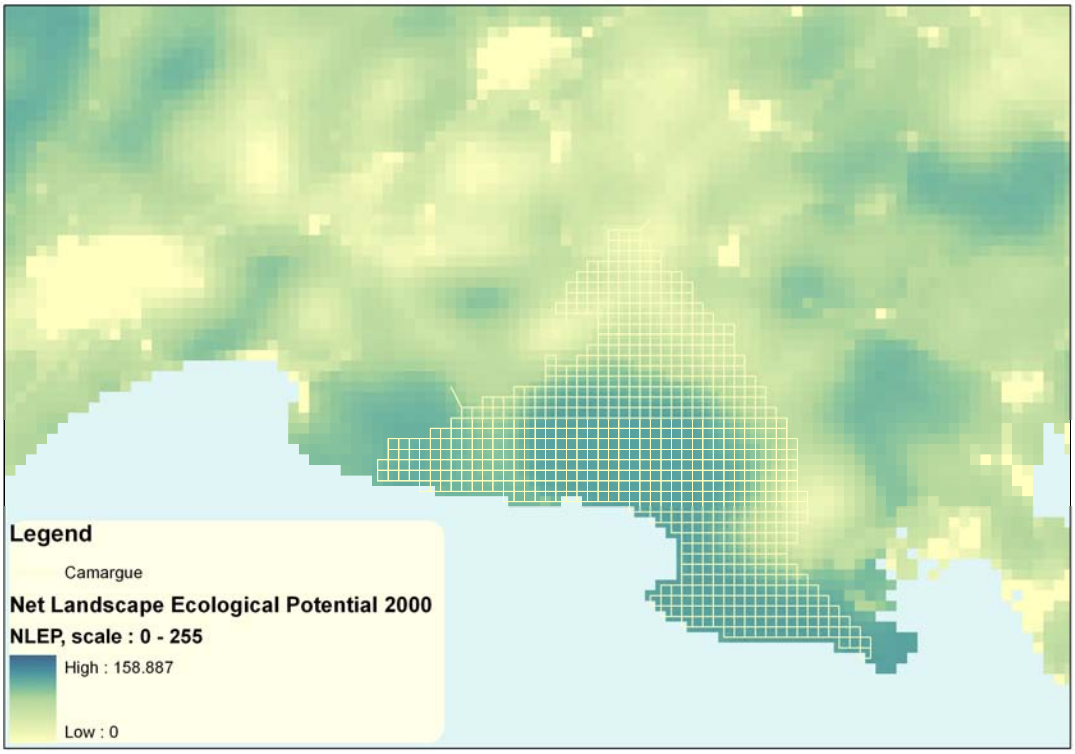


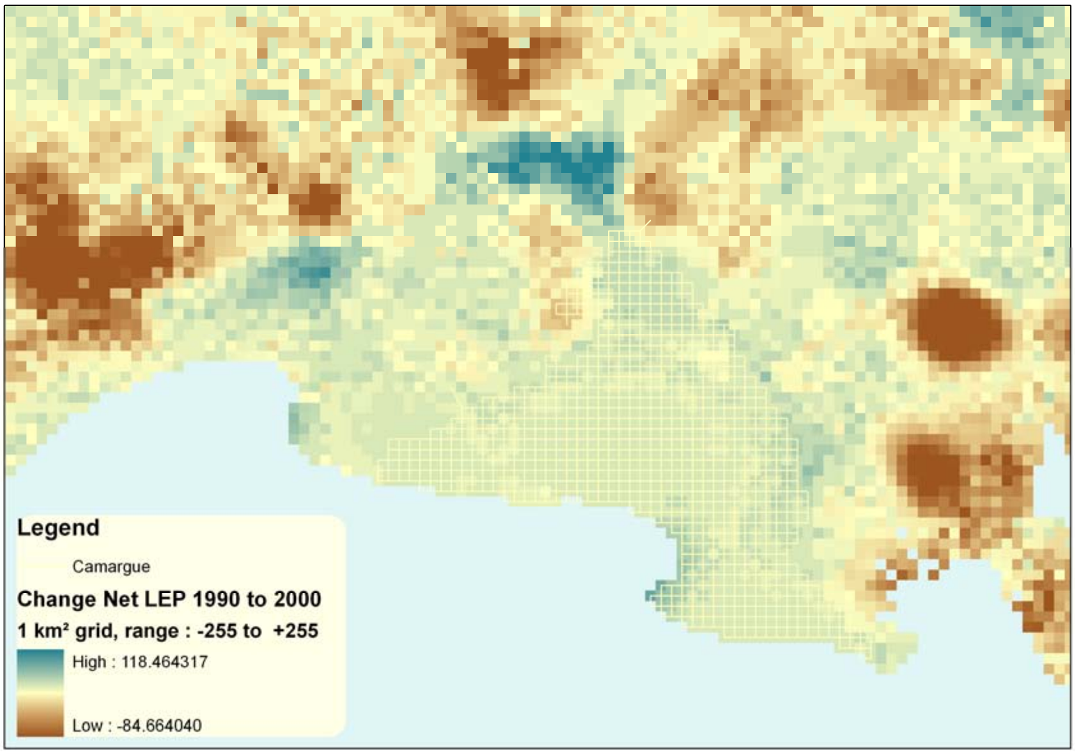
Legend
Camargue
Land cover flows 1990-2000, 1 ha resolution
Urban internal development
Urban residential sprawl
Sprawl of economic activities
Sprawl of sport and leisure facilities
Agriculture internal conversions
Conversion of forest and other land to agriculture
Conversion from wetlands to agriculture
Withdrawal of farming
Forest internal conversions
Water bodies creation and management
Change due to natural and multiple causes

Land and ecosystem physical aggregates:

		Units	CAMARGUE FRANCE
Surface of coastal SES Wetlands		km²	827
TOTAL VALUES IN SES	Urban temperature 2000	0-100	268
	Change in Urban temperature 1990-2000	0-100	14
	Intensive Agriculture Temperature 2000	0-100	20701
	Change in Intensive Agriculture temperature 1990-2000	0-100	814
	Landscape Net Ecological Potential 2000	0-100	83228
	Change in Landscape Net Ecological Potential 1990-2000	0-100	-1513
	Nature designation index (combined N2000 & national)	0-100	79452
	Effective Mesh Size 2005	logN(MEFF)	124672
	Population 2000	inhabitants	21917
MEAN VALUES PER KM² IN SES	Urban temperature 2000	0-100	0.32
	Change in Urban temperature 1990-2000	0-100	0.02
	Intensive Agriculture Temperature 2000	0-100	25.03
	Change in Intensive Agriculture temperature 1990-2000	0-100	0.98
	Landscape Net Ecological Potential 2000	0-100	100.64
	Change in Landscape Net Ecological Potential 1990-2000	0-100	-1.83
	Nature designation index (combined N2000 & national)	0-100	96.07
	Mean Effective Mesh Size in SES 2005	logN(MEFF)	150.75
	Population Density (inhab/km²) 2000	inhabitants	27

These indicators can be mapped with the same 1km^2 grid:


Legend
Camargue
Net Landscape Ecological Potential 2000
NLEP, scale : 0 - 255
High : 158.887
Low : 0


Legend
Camargue
Change Net LEP 1990 to 2000
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Introduction: Getting into the Camargue socio-ecosystem

The Camargue big ecosystem –also identified to the Rhone delta, is a Socio-Ecosystem (SE) located in the southern Mediterranean France. The whole deltaic system covers an area of 1450 km^2 of which 15% is under different protection figures (Tamisier and Dehorter, 1999). A general description of its key features is highlighted in table 1.

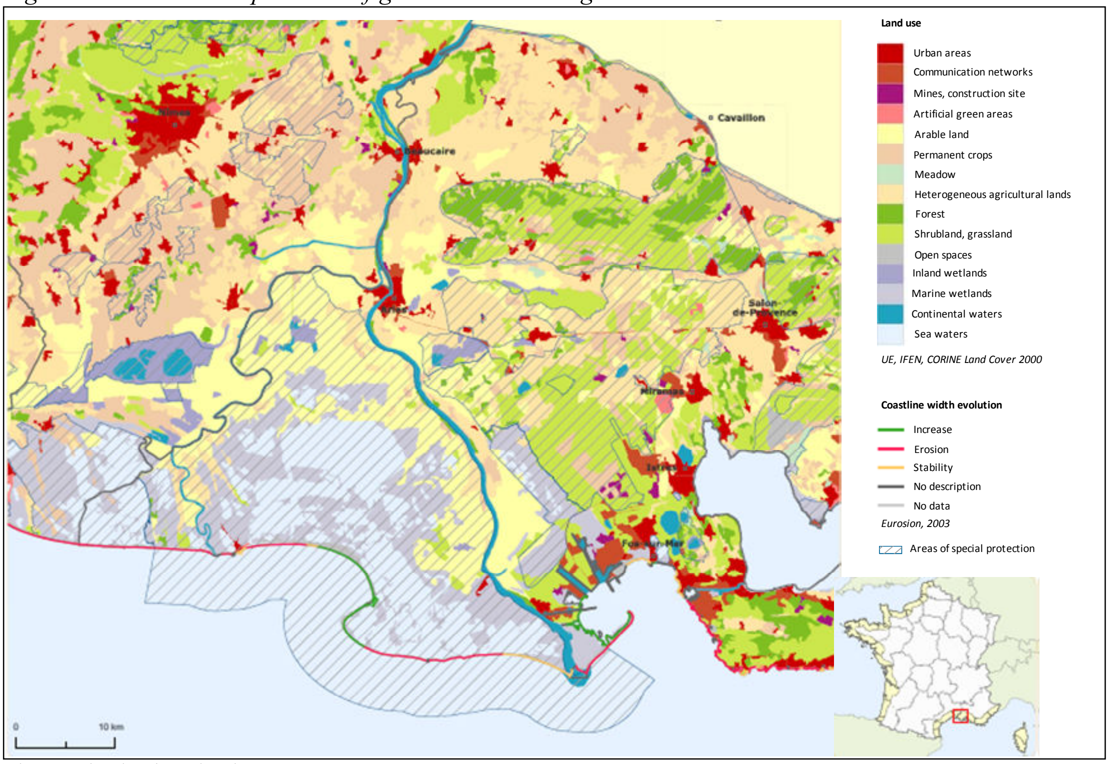
Table 1. General view of the Camargue Socio-Ecological Services (SES).

Characteristics	Description
Location	Bouches du Rhône department, Provence Alpes Côtes d'Azur province, South-east France
Spatial extent	145.000 ha
Biophysical system of reference	Rhone paleo-deltaic system (145.000 ha)
Municipalities	12 (Arles, Aigues-mortes, Aimargues, Beauvoisin, Cailar, Grau-du-roi, Saint-gilles, Saint-laurent-d'aigouze, Vauvert, Port-saint-louis-du-rhône, Fos-sur-mer, Stes Maries de la Mer, A)
Municipalities population	120.214 inhabitants
Main natural reserves (public ownership)	Camargue National Reserve, Scamandre Reserve, Impérial Malagroy, la Palissade
Natural protected areas (mainly over private lands)	Camargue Natural Regional Parc, Ramsar and Biosphere Camargue Reserve, Camargue Gardoise Natura 2000, Camargue Natura 2000
Wetland ecosystems	Vaccarès system (bracksih); Salineworks (hipersaline) ; Aigues-Mortes wetlands-Vigueiras-hunting marshes (freshwater wetlands)
Main ecosystem services	Agriculture, cattle farming, tourism and recreation, research, water purification, refugee for biodiversity, hunting
Other ecosystem services	Fishing, sea food, education, nutrient cycling
Characterization of economic system	Market globalised economy (salt), subsidized agriculture (rice, dry crops)
Characterization of political and administrative institutions	Local: Natural Regional Parc, Syndicates, Majors. Reg./Nat.: Direction de la Nature, MEDAD. International: EU, UN
Religion practices	Christians and Muslims
Environmental problems and disturbances related to human appropriation of provisioning services	Floods, diseases outbreaks, oscillation of ecosystem products prices
Ecosystem disturbances related to human activities	Loss and degradation of wetlands
Methodology used in this work	Maps, bibliographic revisions, statistical data, interviews

Mathevet, 2000. Perennou & Aufrey, 2007.

The Camargue consists on a variety of ecosystems defined by the submersion/drying out water dynamic and the west/east gradient of sand/clay soils. These factors, coupled with the connection to fluvial and/or marine waters, define the two main ecosystem functional units: a fluvial-riparian fresh water wetland system in the upper Camargue (920 km^2) and a marine-riparian wetland system in the central and southern parts of the Camargue, with brackish and salty waters (with an area of 410 km^2) (Figure 1).

Figure 1. Land use and protection figures in the Camargue SE



Observatoire du Littoral web ressources

Because of its variety of habitats, water availability, connection with the Mediterranean landscape and as part of the ecological corridor for European migratory birds, the Camargue performs a series of key ecological functions: habitat provision, specific diversity maintenance (birds, insects, and amphibians), water purification and nutrient cycling (Isenman, 2004). From these ecological functions, humans have traditionally derived a number of important environmental services that are still highly demanded into the regional and local economy: high primary productivity and agriculture production (i.e. rice production), maintenance of fresh water hunting marshes for the selling of lucrative hunting access, water purification (with a number of local biological purification plants based on water filtration through *Phragmites* roots), fishing, salt production and tourism derived income (Mathevet, 2000; Perennou & Aufrey, 2007).

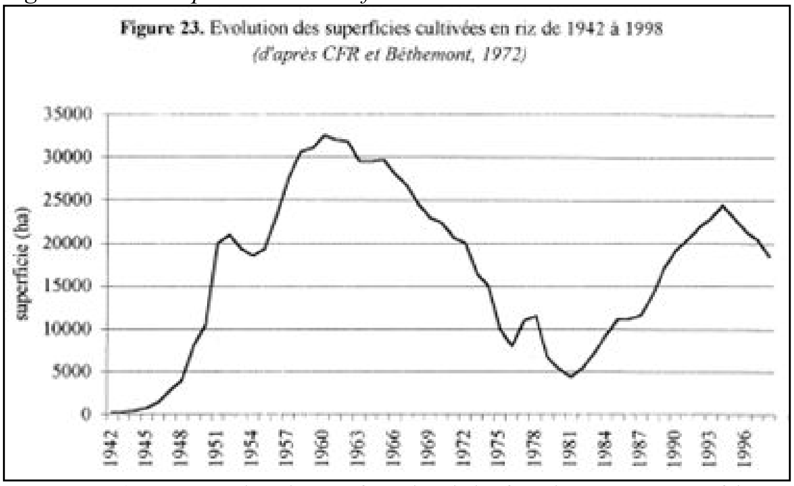
Such environmental services are thus driven by past and present human ecosystem management, which have transformed the Camargue ecosystem functional units into different socio-ecosystems used by local and regional inhabitants for the provision of specific environmental services: the fluvial-riparian unit is now composed of fresh water wetlands for hunting purposes – with a saline concentration of <5g/l, covering an area of 350 km^2 and maintained through a strong water inflow control, natural freshwater wetlands –covering 70 km^2- and rice and dry agriculture areas in the Rhone flood plain – covering 500 km^2; the riparian-marine unit is now composed of brackish natural wetlands

-160 km^2- and salt works –covering an area of 250 km^2 (Tamisier & Dehorter, 1999). Such ecosystem transformation rate and associated economic and biodiversity accounting issues are the central issue of the present chapter, as we shall discuss next.

Transformations and drivers of change in the Camargue in the late 19th and 20th century.

The main hydrological interventions that shaped the Rhone delta as is known at present occurred along the second half of the 19th c. Although dykes had been built as early as the 16th century, the delta was finally enclosed between dykes between 1856 and 1859 to isolate the southern wetlands from marine water inflows and to stabilize the two main Rhone branches and protect lowlands from floods. Such intervention reduced river water and sediment inputs and stopped the geomorphologic changes of the whole Rhone delta. Nevertheless, the driving forces of these fluvial engineering interventions were to obtain agricultural and urban lands, what has lead to a gradually more complex socio-ecosystem. Intensive agriculture first started through vineyard production with a peak of 3.600 ha in 1890. Rice cultivation started in 1900 with a heterogeneous total surface evolution during the 20th century depending on a variety of contextual conditions (see figure 2). It is important to note that this rice surface fluctuation has not provoked a decrease in the total agricultural area, which has maintained a surface above 50.000 ha since 1984.

Figure 2. Rice crops cultivated surface evolution.



C.F.R., 2000. (Note: C.F.R. data always refer to the whole of South France: 90-95% of the production belong to the Rhone delta)

Salt production started in the Vaccarès lake in 1855 but stopped after it was sold and converted into a National Reserve in 1928. It was not until 1960 that salt works increased its surface reaching almost 25.000 ha in 2007 (Insenman, 2004).

The 1928 National Reserve of Vaccarès was the first attempt to value and protect the Camargue ecosystem specific diversity. Since then, and particularly after the 1950's, a number of protected areas have been declared, under a variety of management regimes and institutions, frequently overlapping to each other (see table 2).

Table 2. Main protected areas in the Rhone delta and creation year.

Nom	Surface	Année	Natura 2000	Acquisition
Camargue National Reserve	13117	1927		x
Tour du Valat	1588	1948		x
Impériaux lake	2930	1962		x
Palissade	702	1977		x
Consécannière	570	1980		x
Ligagneau	449	1982		x
Etourneau	453	1988		x
Bardouine	345	1992		x
Giraud	349	1993		x
Camargue	114126	1986	x	
Le Rhône Aval	12606	1998	x	
Marais entre Crau et Grand Rhône	7234	2000	x	
Camargue Gardoise Fluvio-Lacustre	5723	2001	x	
La Camargue Gardoise	30580	2002	x	
Le Petit Rhône	808	2002	x	
Camargue	112531	2003	x	
Marais de la Vallée des Baux et Marée d'Arles	11074	2004	x	
Petite Camargue Laguno-Marine	15681	2006	x	

Perennou & Aufrey, 2007.

Nevertheless, strict protection covers only 23.648 ha, whereas the rest of the Camargue natural and human managed areas are protection schemes that negotiate management regimes with private landowners, the main actors of the Natura 2000 network in the Camargue.

Basic Land Ecosystem Accounting for the Camargue SES

Human driven land use changes and ecosystem services in the Camargue respond to a productive approach linked to a specific socio-economic context. Such interrelation sets the general scene for the application of the LEAC methodology: how to quantify the tradeoffs between biodiversity, economic ecosystem services and land use to prospect possible links with past, present and future ecosystem management policies (Table 3).

Table 3. Historical evolution of the Camargue coupled socio-ecosystem.

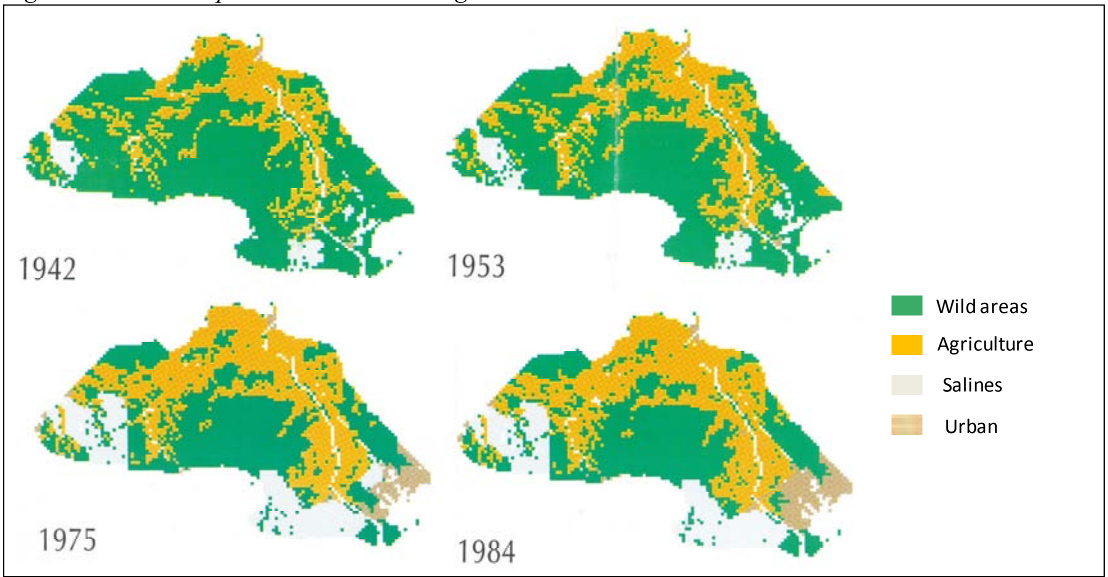
Period	*Land use patterns*	*Socio-economic context*
Pre-Roman	Hunting, fishing. Limited agriculture under environmental constraints	Subsistence economy
Roman / Middle ages	Large land holdings, agriculture in river banks	Productivism under religious and military rule
XV-XVIII c.	Hunting, fishing. Limited agriculture under environmental constraints	Productivism, commerce and artisan development
XIX c.	Large land holdings, vineyard and cattle development. Construction of Rhone and marine dykes	Industrial revolution, capitalism, commerce, scale investments
XX c.	Large land holdings, rice crops, hunting, natural reserves and tourism development, anthropic wetland water management	Capitalism, protectionnist agriculture market and globalisation. Political ecology

Mathevet, 2000

Land cover accounts

Main land use changes in the Camargue took place between 1953 and 1975 (figure 3) driven by the increase in rice crops, salt works and industrial areas (table 4). From 1942 to 1984, 72 km^2 of lakes, 13 km^2 of forest, 150 km^2 of marshes and 186 km^2 of salt steppes were transformed into human managed areas (Tamisier, 1990).

Figure 3. Natural capital loss in the Camargue marshes since 1942.



Tamisier, A. 1990

This loss of natural capital has been directly associated with the development of 80 km^2 of industrial areas, 100 km^2 of rice, 80 km^2 of dry crops and 153 km^2 of salt works (see Box 1). The table below present those surface changes in detail.

Box 1. The Camargue dramatic wetland loss during the "Trente Glorieuses".

After the end of the Second World War, and all along the national economic growth period named as the "Trente Glorieuses" (1950-1980), the Camargue wetland system got progressively dried, and transformed into urban, industrial and agricultural areas. Between 1942 and 1984, 40.000 ha of natural wetlands were lost (Figure 3). The transformation of natural wetlands into rice and dry crops, cattle farms, saltworks and industrial areas was never assessed under a comprehensive accounting framework. Ecosystem functions and services got disturbed and degraded for the profit of few provisioning services. The dramatic relevance of such change arises because of the lack of methodological reviews on ecosystem accounting changes: the only research work developed under a time series approach was developed by A. Tamisier in the 1980's (Tamisier, 1984). Until now, no other research works had dealt with the need to adopt an ecosystem accountability under a strong spatial and timely basis.

Table 4. Changes in land cover in the 1942-1984 period.

Land cover (ha)	1942	1953	1976	1984
Water bodies (lakes, reservoirs)	21675	21200	14500	14450
Salt marshes	7650	6475	3175	3025
Salt steppes (sansouïre), grassland	33875	27825	15500	15200
Inland marshes	29375	29950	19625	18625
Forest	4425	4200	3375	3100
Salines	5625	6875	22150	20950
Agriculture	33950	19850	42950	41975
*Industrial**	575	650	5825	8550
Rice	300	20000	8500	10000
other	7550	7975	9400	9125
Total	***145000***	***145000***	***145000***	***145000***

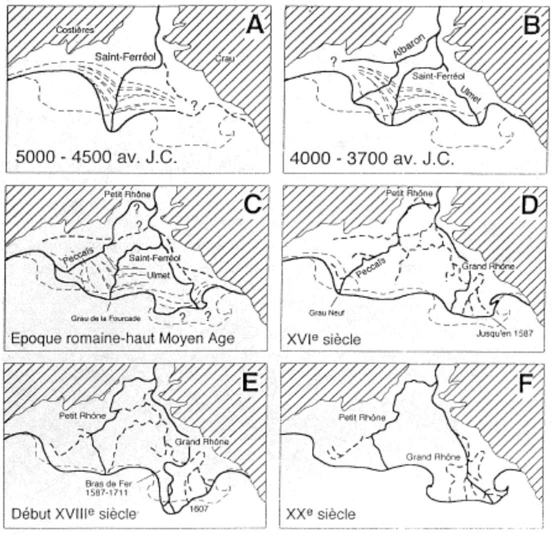
* Figures for industrial land-use are over-estimated for the period 1976-84 as all land bought for future industrial developments was accounted as lost for the environment, although large areas still remain nowadays as wetlands

Lemaire et al., 1987.

Water accounts

As discussed above, the most important hydrological management actions took place from the mid 19th c. onwards (Bethemont, 1972), with the final result of fixing the Rhone river main streams migration and to protect lowlands from floods (Figure 4).

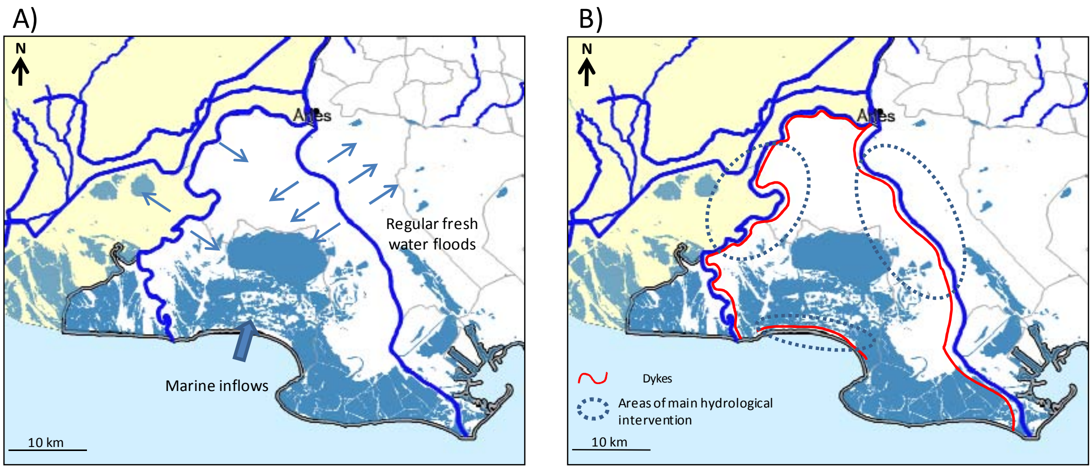
Figure 4. Rhône delta transformations.



Bethemont, 1972

In addition to the wetland reduction by land use changes, the hydrological interventions greatly reduced tidal and marine influence to marshes, and water and sediments inputs associated with seasonal floods (figure 5).

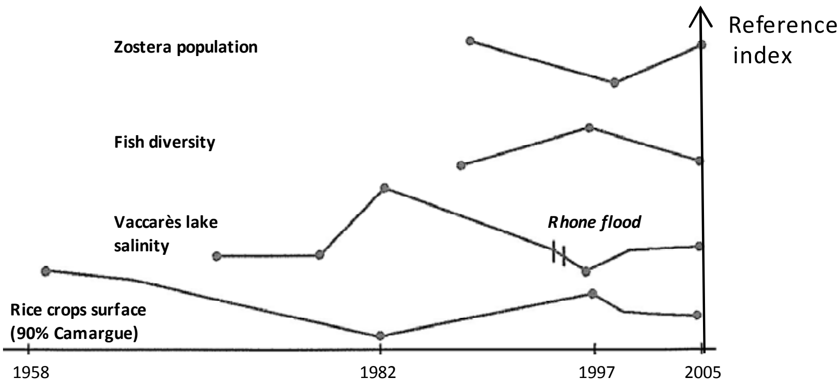
Figure 5. A) Water natural inflows at the early 19th century. B) Hydrological fluxes disturbances after main hydrological works in the late 19th c. and early 20th c.



Few works have dealt with the Rhône sediment charge loss due to upper river dams (Fruget, 2003; Sabatier, 2001). These studies appoint a loss of 34 million t/year of sediment reduction from 1847 to 1993 due to river dams. The present total amount of transported sediments by the Rhône river was quantified by these same studies as 8 million t/year: we could then argue then due to Rhône dykes, the Camargue flood plain is losing 8 t/year of sediments, from a potential sediment discharge of 42 million t/year.

Moreover, the existence of dense network of canals connecting the upper wetlands to both Rhone streams, have introduced a great human driven variability for key ecological factors like water level and hence salinity (PNRC, 2004). Therefore, the variable seasonal water needs of rice crops and hunting marshes private lands –under private lands- determines the net freshwater inflow from the Rhone canals to the Camargue wetlands what defines at last the saline concentration and the presence of saline or fresh water dependent communities in the Camargue (Figure 6).
These population dynamics has introduced a degree of complexity to the management of the Camargue socio-ecosystem, where the lack of a comprehensive accounting of the real tradeoff between biodiversity changes and ecosystem services is one of the main medium and long term threats for its economic and ecological management.

Figure 6. Correlated trends between fresh water inflows, wetlands salinity, rice cultivation and communities specific diversity changes.



Perennou & Aufrey, 2007

Another important issue related to wetland services and water accounts is pesticide used for rice cropping, which pollutes water. Indeed, the Camargue wetlands and specially the Vaccarès lagoon system is polluted by –mainly- four herbicides; pretilachlor, bentazone, oxadiazon and MCPA. Different research works have dealt with the description and modeling of its life cycle, its behavior in the wetland system and bio-chemical degradation in (see Comoretto et al., 2007a and 2007b for France; Nakano et al., 2004 for Japan).

What's the role played by the Camargue wetland ecosystem functions in degrading such pesticides? The answer is complex because of the different physic-chemical characteristics of such complex compounds. For instance, while MCPA and bentazone herbicides are soluble in water and do not get absorbed by organic matter, pretilachlor and oxadiazon present just the opposite physic-chemical behavior. Different ecosystem functions will then influence each of them. We adapt Comoretto et al. (2007a) research work, to understand how ecosystem functions have developed the ecosystem service of water depuration for these four pesticides (see Table 5).

Table 5. Wetland functions implicated in the ecosystem service of water purification through herbicide degradation.

	wetland habitat	***water bodies***	***water bodies***	***water bodies***	***soils***	inflow average concentration (µg/l)	outflow average concentration (µg/l)	concentration reduction (µg/l)
	wetland function	*dilution*	*volatilization/ photodegradation*	*biodegradation*	*sediment sorption*			
Pesticide	pretilachlor			x	x	7,3	1,9	5,4
	bentazone	x	x					
	oxadiazon				x			
	MCPA	x	x					

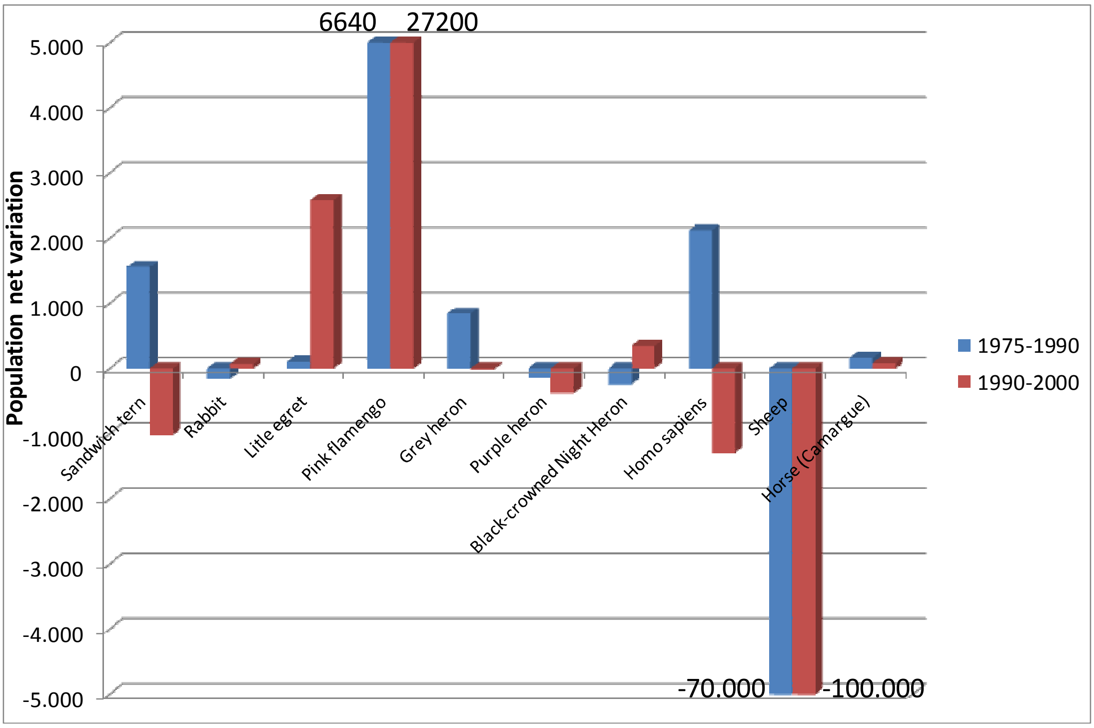
Modified from Comoretto et al., 2007a

The average inflow (ditches) and outflow (lwetlands) concentration of pretilachlor, bentazone, oxadiazon and MCPA was measured. The different ecosystem functions were able to reduce the initial herbicide pollution from 7,3µg/l to 1,9µg/l what supposed a decrease in 74% of the agricultural water herbicides pollution .

Species accounts

Species population changes from 1975 to 2000 shows a complex pattern (Figure 7). Indeed, species responds to a number of external stressors that are defined by their autoecology. Birds, fishes, amphibians, mammals all respond to a specific array of socio-ecosystem dynamics that may or may not converge. Birds' population dynamics for example, are subject to a number of complex responses to environment variability: land use patterns and management practices –hunting, cropping- may have a comparable influence to population size than wintering survival rate (Barbraud and Hafner, 2001). Indeed, while ducks and coots seem to be highly affected by hunting activities (Tamisier and Dehorter, 1999), and purple/grey herons affected by reed bed harvesting, their population may vary in turn by other environmental stressors like the wintering survival rate above mentioned. This results in a varied population change (Figure 7). Another example is the Flamingo's case: the knowledge on Flamingos' autoecology and its associated habitats within salines areas has oriented strong conservation efforts towards protecting such nesting and feeding habitats, of a valuable economic productivity too, what has finally resulted in an increase and stabilization of its population. While the link between land use patterns, ecosystem services provision, agri-environmental policies and species' population dynamics it is still a challenging debate, more examples on populations' decrease or increase by direct land use changes may help understanding the issue. This is the case of sheep versus horse or bull populations. While sheep are still abundant in other nearby wetlands, specific land use and cattle choices in the Camargue have almost totally precluded such specie from that area.

Figure 7. Selected species population fluctuations between 1975 and 2000.



Tour du Valat data

Ecosystem services of the Camargue SES

As we have argued in the present report, the Camargue SES has undergone important mutations in the last century. Hydrological management, agriculture, salt works and industrial development in one side, versus strict conservation reserves in the other side, have been the main drivers of change of the Camargue SES.
As a result of such opposite land use patterns, and the derived user groups interests, the intellectual knowledge, statistics and scientific capital have remained sectorial: conservation groups have remained attached to the monitoring of specific communities or general land use change analysis, while user groups attached to main economic activities have not interacted actively with the scientific community in terms of continuing data sharing and communication. At the regional level, statistics and monitoring have remained at a descriptive level, and scattered between institutions and organizations.
The LEAC methodology and the analysis of ecosystems as complex open social-ecosystems are indeed revealing the need of such transdisciplinary approach, both in terms of monitoring, institutional synergic work and scientific research.
Therefore, data availability is good in terms of physical measurement of ES (Table 6) but extremely scarce in terms of economic concrete ES value (Table 7). Data on conservation expenses for the Regional Parc of Camargue are on the contrary available (Table 8).

Table 6. Physical measurement of some ES in Camargue wetlands (and coastal waters for fishing)

ES	Qantities

Rice	120.000 t
Dry crops	15.000 t
Vineyard (grapes)	3.100 t
Cattle farming	23.000 animals
Fishing (Camargue coast)	4.000 t
Tourism	500.000 visitors/yr
Refugee for biodiversity	5684 recorded sp.
Sustainable crops (reed bed)	3.500 ha
Hunting (ducks)	150.000 preys
Salt production	1500.000 t

Mathevet, 2000; Perennou & Aufrey, 2007.

Regarding economic value, deeper problems arise, like the existence of a strong black market economy for getting access for hunting into private fresh water marshes (see Box 2).

Table 7. Recorded economic value for some Camargue ES.

ES	Annual value € (2000)
Provisioning services	
Rice	32.931.849
Dry crops	2.798.889
Vineyard (grapes)	n.d.
Cattle farming	n.d.
Fishing (Camargue coast)	n.d.
Sustainable crops (reed bed)	960.512
Hunting (ducks)	See Box 2
Salt production	n.d.
Regulating services	
Refugee for biodiversity	n.d.
Water purification	n.d.
Socio-cultural services	
Tourism	n.d.

Mathevet, 2000; Perennou & Aufrey, 2007.

Table 8. Overall budget of the Natural Regional Park of Camargue

	2005	2006	2007	2008
Staff and other fix costs	1 490 000 €	1 600 000 €	1 650 000 €	1 600 000 €
Field actions' budget	254 000 €	760 000 €	790 000 €	1 020 000 €
TOTAL	1 744 000 €	2 360 000 €	2 440 000 €	2 620 000 €

PNRC, 2008.

Box 2. The black market economy surrounding hunting permits.
Private landowners in the surrounding of the Vaccarès central lake maintain artificial freshwater wetlands all along the year for ducks. Foreign hunters get access to such private artificial freshwater wetlands after paying an important stumpage fee, not declared to the authorities. This hunting access informal stumpage fee represents an important source of income in the rural Camargue (Mathevet, 2000). Besides, hunting is strongly affecting duck populations and behaviour (Mathevet & Dehorter, 1999). The lack of comprehensive statistics and a robust LEAC accounting prevents the implementation of effective policies to control hunting derived income and duck's population loss.

This problematic is more urgent in the present deep integration of Camargue ES in the local, regional and national markets (Table 8). Recent ecosystem disturbances, like the high PCB concentrations found in the whole Rhone river catchment basin that have provoked the ban of fishing in all Rhone associated fresh waters, have not been coherently quantified in terms of economic and ecological functions impacts (SIEAU, 2008). This in turn, implies that preventive and corrective policies are less effective. Other cases may support such urgent need to implement a comprehensive LEAC methodology in the Camargue: to protect heron populations, the farmers have received important economic subsidies to support a heron nesting oriented management of reed beds. Results have not still been quantified, and the cost-effectiveness of such policies needs to be assessed to spread in the region.
Besides, recent fluctuations in salt price are driving new land use changes, and the Company of the Salines –in east Camargue- is preparing to transform part of its salt works in natural areas while converting another part of it into urban areas (J.-P. Taris, Sansouïre Foundation Executive President, pers. comm.). Agreements between local public and private institutions have been achieved, but although such issues are deeply embedded into LEAC issues, the land use agreement has precluded such analysis.

Table 8. Degree of integration in markets of the Camargue ES.

Carrier		Service-type		Category		Service	Full	Partial	None
Production	1	Provisioning	1.1	Food	1.1.1	Hunting	x		
Production					1.1.2	Salt production	x		
Production					1.1.3	Fishing	x		
Carrier					1.1.4	Livestock		X	
Carrier					1.1.5	Agriculture	x		
Production			1.2	Materials	1.2.4	Fiber crops	x		
Information	2	Socio-Cultural	2.1	Recreational	2.1.2	Ecotourism		X	
Information					2.1.3	Landscape beauty		X	
Information			2.3	Didactic	2.3.1	Education / interpretation		X	
Information					2.3.2	Scientific research		X	
Information					2.3.3	Traditional Ecological Knowledge		x	
Regulation	3	Regulating	3.1	Cycling	3.1.1	Soil retention & Erosion control			X
Regulation					3.1.2	Hydrological regulation	x		
Regulation					3.1.4	Pollination for useful plants		X	
Regulation					3.1.5	Climate regulation		X	
Regulation			3.2	Sink	3.2.1	Soil purification			x
Regulation					3.2.3	Water purification		x	
Regulation			3.3	Prevention	3.3.2	Pest prevention			X
Regulation					3.3.3	Invasive species prevention			X
Regulation					3.3.4	Air quality			x

Under the present context, highly relevant studies appointing at what policies would be more effective –40.000 ha of natural areas under private management could be bought at a cost of 3.812 €/ha, a total 150 million € cost under 1991 land and money values (Tamisier, 1991)- cannot bet effectively assessed. Moreover, the Camargue case study clearly shows that the lack of a LEAC comprehensive approach leads to unavoidable land use, biodiversity management, and regional sustainable development inaccurate sectorial policies.

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5.4. The Danube Delta – an open socio-ecological system (SES)

Preamble: The Danube Delta seen from Europe or the LEAC story

Land cover accounts can give a first useful picture of the Danube Delta and its recent evolution. This picture presents the park in its (land cover) environment and offers gateways to the broad European picture as well as to other sites with which comparisons are fruitful. These accounts being based on a grid (on the following maps, a 1 km2 gird is used) they are an efficient framework for integrating socio-economic statistics and ecological monitoring data.

First, the Corine map:

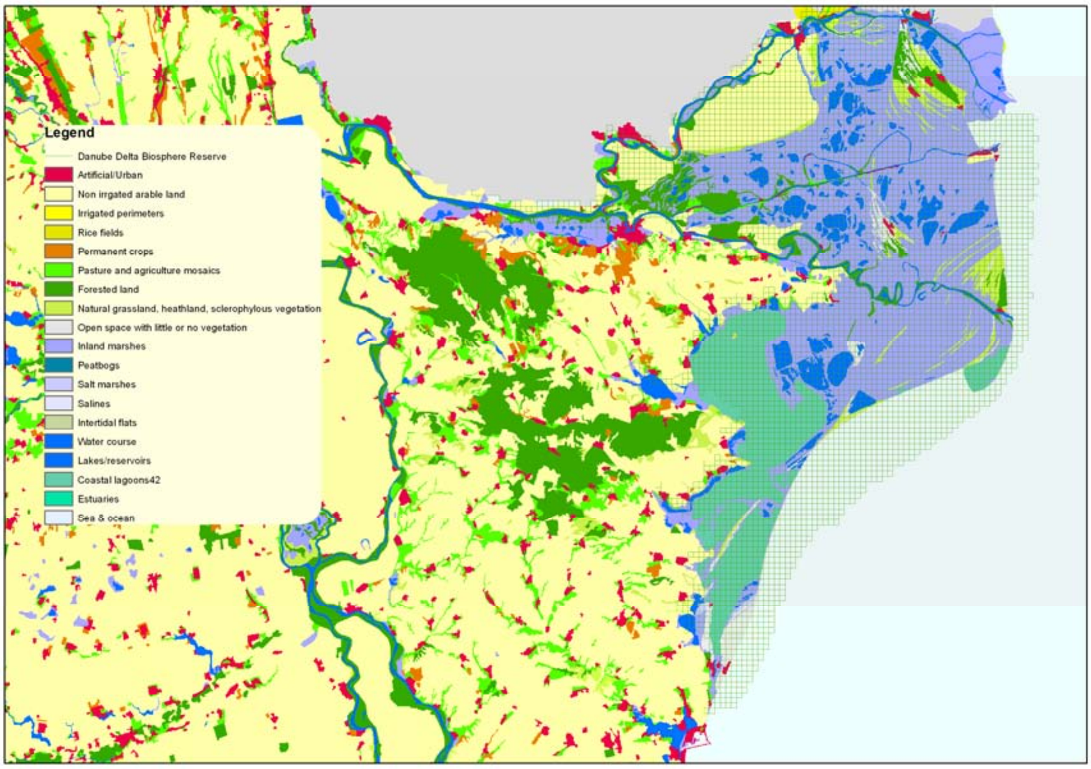


Figure 5.4.x Danube Delta land cover; CLC2000

The same tables as produced for the whole Mediterranean basin can be established for the site. They tell about:

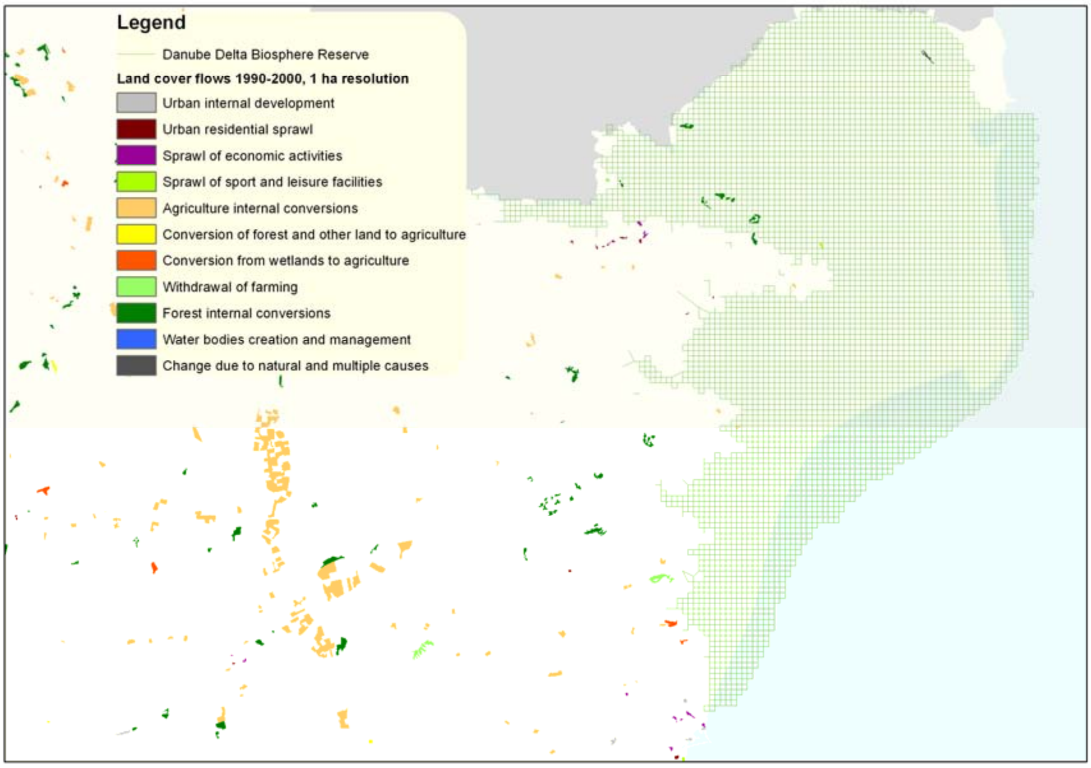
- Land cover

		Danube Delta		
		1990	2000	Net change
111	Continuous urban fabric			0
112	Discontinuous urban fabric	4624	4624	0
121	Industrial or commercial units	421	447	26
122	Road and rail networks and associated land			0
123	Port areas	139	139	0
124	Airports			0
131	Mineral extraction sites	193	193	0
132	Dump sites	139	139	0
133	Construction sites	56	56	0
141	Green urban areas			0
142	Sport and leisure facilities	140	179	39
211	Non-irrigated arable land	60393	60274	-119
212	Permanently irrigated land			0
213	Rice fields			0
221	Vineyards	623	584	-39
222	Fruit trees and berry plantations	208	208	0
223	Olive groves			0
231	Pastures	2447	2408	-39
241	Annual crops associated with permanent crops			0
242	Complex cultivation patterns	898	898	0
243	Agriculture mosaics with natural vegetation	181	181	0
244	Agro-forestry areas			0
311	Broad-leaved forest	21456	21491	35
312	Coniferous forest			0
313	Mixed forest			0
321	Natural grassland	18355	18253	-102
322	Moors and heathland			0
323	Sclerophyllous vegetation			0
324	Transitional woodland shrub	3253	3218	-35
331	Beaches, dunes and sand plains	6008	6110	102
332	Bare rock			0
333	Sparsely vegetated areas	7174	7174	0
334	Burnt areas			0
335	Glaciers and perpetual snow			0
411	Inland marshes	210151	210283	132
412	Peatbogs			0
421	Salt marshes	815	815	0
422	Salines			0
423	Intertidal flats			0
511	Water courses	8008	8008	0
512	Water bodies (lakes & reservoirs)	42179	42179	0
521	Coastal lagoons	68732	68732	0
522	Estuaries			0
523	Sea and ocean			0
	TOTAL	**456593**	**456593**	**0**

- Land cover flows 1990-2000

		Danube Delta
		Flows 1990-2000
lcf12	*Recycling of developed urban land*	
lcf21	*Urban dense residential sprawl*	
lcf22	*Urban diffuse residential sprawl*	
lcf31	*Sprawl of industrial & commercial sites*	26
lcf35	*Sprawl of mines and quarrying areas*	
lcf37	*Construction*	
lcf38	*Sprawl of sport and leisure facilities*	39
lcf412	*Diffuse extension of set aside fallow land and pasture*	
lcf421	*Conversion from arable land to permanent irrigation perimeters*	
lcf422	*Other internal conversions of arable land*	
lcf433	*Other conversions between vineyards and orchards*	
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*	
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*	39
lcf444	*Diffuse conversion from permanent crops to arable land*	
lcf451	*Conversion from arable land to vineyards and orchards*	
lcf463	*Diffuse conversion from pasture to arable and permanent crops*	
lcf511	*Intensive conversion from forest to agriculture*	
lcf512	*Diffuse conversion from forest to agriculture*	
lcf521	*Intensive conversion from semi-natural land to agriculture*	
lcf522	*Diffuse conversion from semi-natural land to agriculture*	
lcf53	*Conversion from wetlands to agriculture*	
lcf54	*Other conversions to agriculture*	
lcf62	*Withdrawal of farming without significant woodland creation*	
lcf71	*Conversion from transitional woodland to forest*	330
lcf72	*New forest and woodland creation, afforestation*	
lcf73	*Forests internal conversions*	
lcf74	*Recent fellings, re-plantation and other transition*	295
lcf81	*Water bodies creation*	
lcf91	*Semi-natural creation and rotation*	102
lcf93	*Coastal erosion*	
lcf99	*Other changes and unknown*	132
	No Change	455630
	TOTAL	**456593**

- These flows can be mapped as well:



And first land and ecosystem physical aggregates:

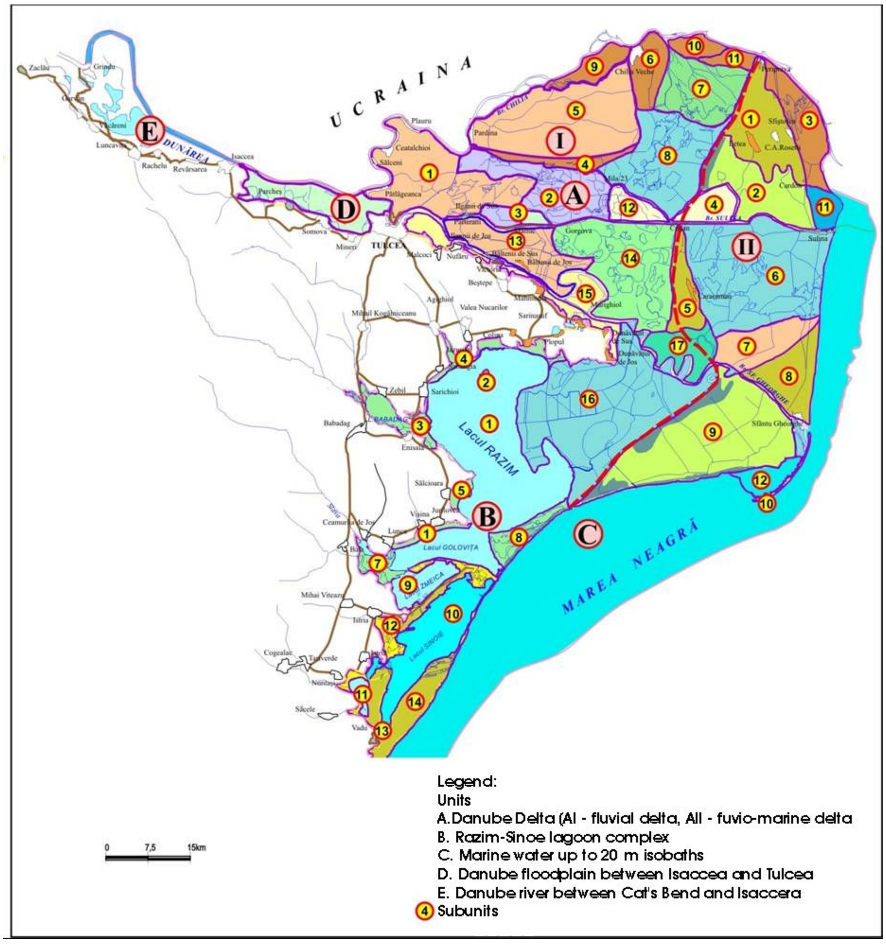
		Units	DANUBE DELTA ROMANIA
Surface of coastal SES Wetlands		km²	5858
TOTAL VALUES IN SES	Urban temperature 2000	0-100	7411
	Change in Urban temperature 1990-2000	0-100	194
	Intensive Agriculture Temperature 2000	0-100	69049
	Change in Intensive Agriculture temperature 1990-2000	0-100	1295
	Landscape Net Ecological Potential 2000	0-100	n.a
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a
	Nature designation index (combined N2000 & national)	0-100	531461
	Effective Mesh Size 2005	logN(MEFF)	n.a
	Population 2000	inhabitants	43702
MEAN VALUES PER KM² IN SES	Urban temperature 2000	0-100	1.27
	Change in Urban temperature 1990-2000	0-100	0.03
	Intensive Agriculture Temperature 2000	0-100	11.79
	Change in Intensive Agriculture temperature 1990-2000	0-100	0.22
	Landscape Net Ecological Potential 2000	0-100	n.a
	Change in Landscape Net Ecological Potential 1990-2000	0-100	n.a
	Nature designation index (combined N2000 & national)	0-100	90.72
	Mean Effective Mesh Size in SES 2005	logN(MEFF)	n.a
	Population Density (inhab/km²) 2000	inhabitants	7

1. The Danube Delta – an open socio-ecological system (SES)

The Danube Delta coupled social-ecological system (SES), situated in South–East Romania, covers 5800 Km² of which 3500 Km², belong to the *delta proper* while the remaining area is shared between the upstream *Danube floodplain in natural regime* (Isaccea-Tulcea sector 102 km²), the *Razim-Sinoie lagoon complex* (1,145 km²), *the marine waters up to the 20 m isobaths* (1,030 km²), and the Danube river between Cat's Bend and Isaccea (13 km²).

These units are embedded by the **Danube Delta Biosphere Reserve** (Fig. 1) which was created through the Decision of the Romanian Government No. 983 of August 1990 and is listed within three international environmental protection networks: the International Convention for the Protection of the World Cultural and Natural Heritage (1990), the Convention of Wetland Zones of World Importance (RAMSAR Convention - 1991) and the International Biosphere Network (UNESCO - M&B program).

Fig.1 The geographical units within Danube Delta Biosphere Reserve (see also Annex 1)

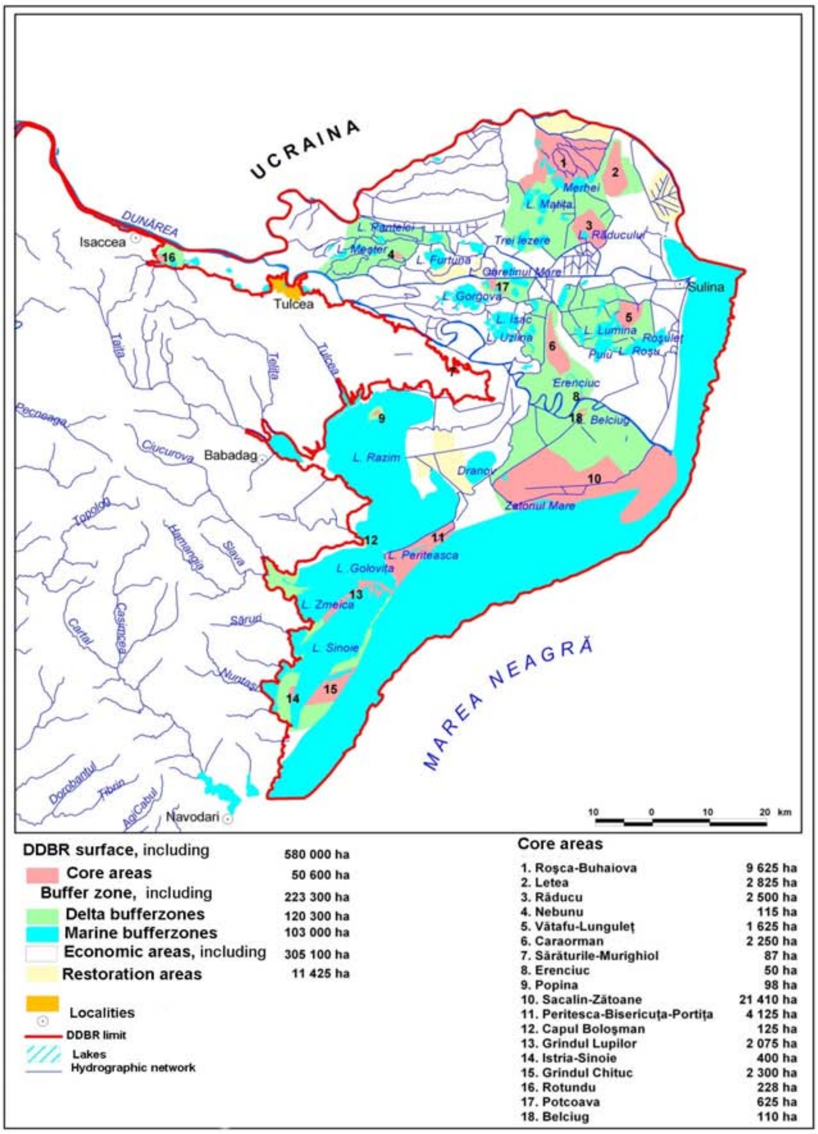


Source: DDNI

On the basis of landforms, morphometric and hydrographical characteristics, the proper Danube Delta is divided in two main subunits: *the fluvial delta*, the oldest part which was developed within the former gulf of the Danube ricer and the *fluvio-marine delta* that extends east of this line, up to the Black Sea.

Inside this territory, the Danube Delta Biosphere Reserve has structured the following areas: *18 strictly protected areas* (506 km2), *buffer zones* (2 233 km2) situated around the strictly protected zones in order to gradually reduce human pressure *and economical zones* (3 061 km2) englobing all settlements and the restoration areas. (Fig.2)

Fig.2 Land use in Danube Delta Biosphere Reserve



1.2 Understanding the Danube Delta Social-Economical System starting with its genesis

All the ideas and hypotheses issued about the genesis of the Danube Delta start from the same point: the delta was created on a **liman** golf carved in the **formations** belonging to the North Dobrudja structures and to the Predobrudjean depression (Fig.3) There is also another idea that the delta is the result of the interaction of the river processes with the maritime ones, marked by eustatic movements of the Black Sea and epirogenetic movements of the foundation.

Between the two main categories of processes, the decisive role was played by the positive and negative eustatism of the sea level, which occurred in the Danubian **liman** golf and in the south lagoonal golf – Halmyris, at present covered by the Razim – Sinoe lacustrian area, marked by transgressions and regressions.

Fig. 3 The Danube Liman and Halmyris gulf

The issued hypotheses fall into two categories. The first one regards the **ingression delta** that is continuous growth and advancing, supported by Gr. Antipa and C. Bratescu. The second one is the **regression delta** that is the withdrawal and diminution of the area, supported by G. Vaslan and, more recently by N. Panin.

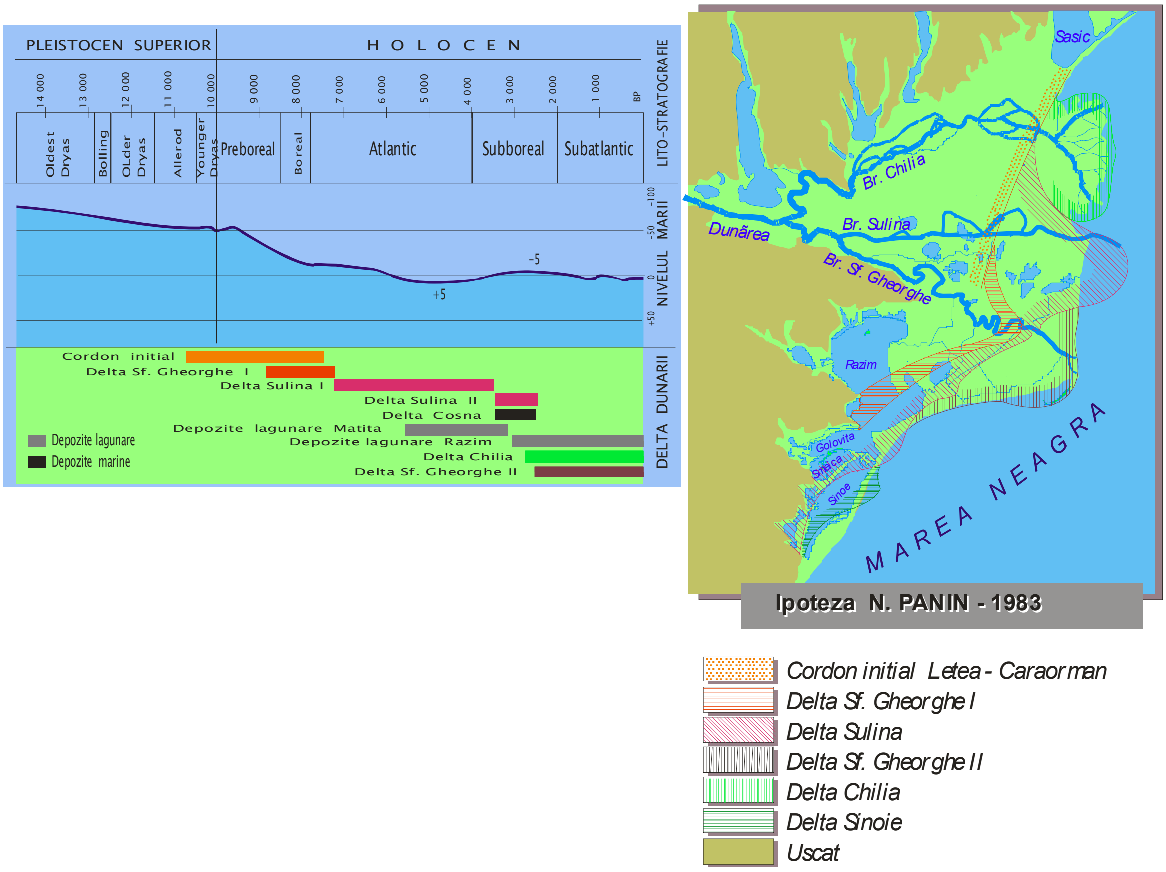
The two categories (ingression and regression) do not exclude each other because there exist a long-lasting tendency – since the creation of the first embryo at least – of the delta to advance in shorter or longer withdrawal periods, depending on the sea level.

At the same time, it becomes obvious that after the formation of the Sulina secondary delta, the delta has been withdrawing as a result of the slight rise of the sea level and of the mini transgression clearly seen on the shore by abrasion processes.

It is estimated that the delta was born 12,000 years ago. The fact was proved by the erosion samples found in the alluvia, the **initial cordon** (10,000 – 9,000 BC) being centered on the line of the sandbanks Jibrieni (Ukraine) – Letea – Caraorman, Romania. (Figure 4)

The Black Sea level had variations with rises and falls with a general tendency of rising. Thus, at the beginning of the Superior Pleistocene (about 14,000 years BC) the level was –70 or –80m, while in the middle of the Holocene – the Atlantic age – (about 5,000 years BC) the level rose at + 5m. Since the Atlantic age up the present the level has varied with ±5m (-5m in the sub boreal age, approx. 2,500 years BC).

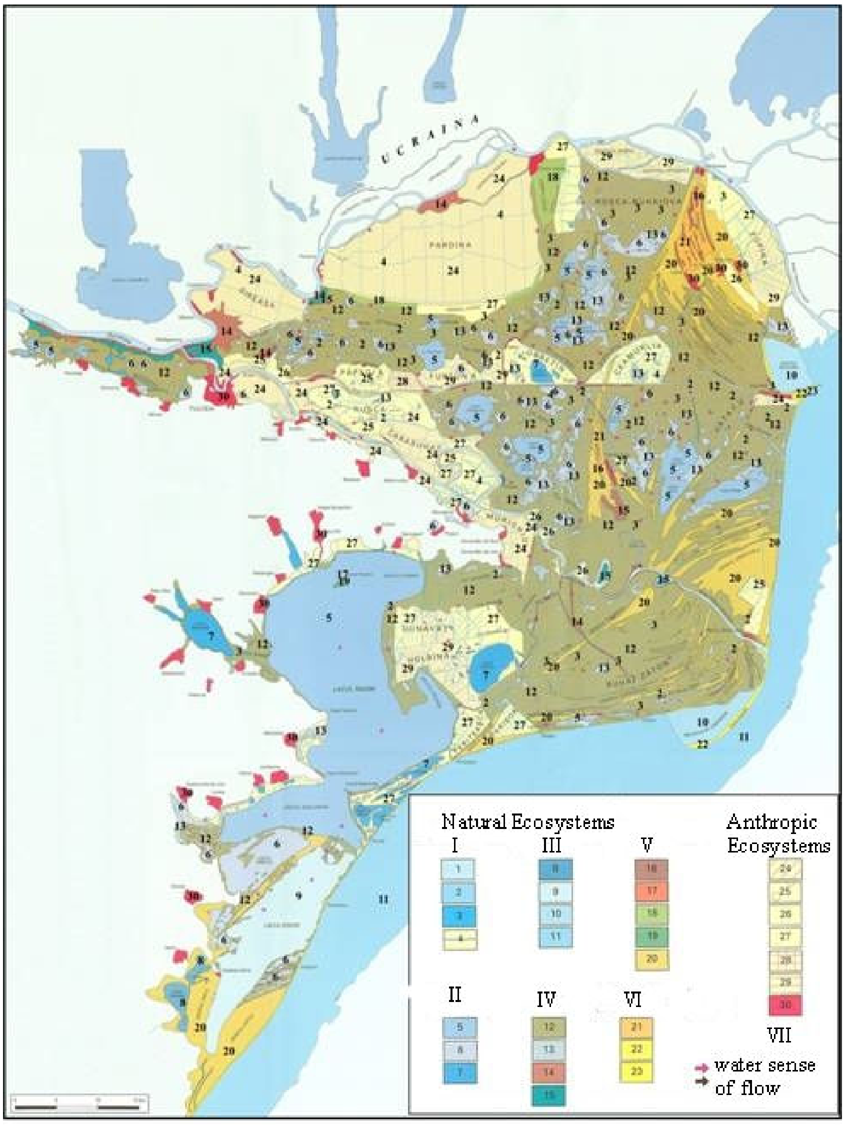
Figure 4 The Delta and Razim – Sinoe Lagoon complex genesis



1.3 Ecosystem – fundamental functional unit of Danube Delta Socio-Ecological System

Taking into account the morphologic-hydrographic configuration of the area, its flora and fauna communities and the long-term human impact, the two main categories of Danube Delta ecosystems associated with the Razim-Sinoe lake complex and the Danube flood plain between Isaccea and Tulcea, as a part of Danube Delta Biosphere Reserve, have been delimited as follows: *natural ecosystems* that comprises 23 types of ecosystems and *anthropic ecosystems* with 7 types (Figure 5, see also the Appendix 2).

Figure 5 The ecosystems of the Danube Delta Biosphere Reserve



Source: Prof. Dr. Petre Gastescu

Because of such diverse type of ecosystems, its location at the intersection of the main European bird migration ways, the water availability, the Danube Delta carries out *different ecological functions*, among the most important is their valve as a place of reproduction for fish, as a resting, feeding and breeding place for birds, as a habitat for mammals, reptiles, amphibians as well as an extremely varied invertebrate fauna. Water retention, groundwater enrichment, water self-purification, genetic exchange, sediment retention as well as retention of nutrients are also functions performed by the Danube Delta.

In order to satisfy the human needs, which include subsistence, protection, affection, understanding, participation, leisure, creation, identity, the Danube Delta's ecosystems not only provide(d) food, fiber, shelter, water, and other services necessary for subsistence, but they also contribute to providing with opportunities for creativity and leisure, giving also a sense of identity. The local/regional economy highly depends on the ecosystem services rendered by the delta's ecosystems, such as *provisioning food* – e.g. fish (local communities rely on fish/fishing that is the most important source of incomes from natural resources), *provisioning ffuel and fibre* (timber from sand forests, and reed having especially household use, aggregates - with industrial use).

Within time, the Danube Delta's ecosystem services are being impaired and destroyed by a wide variety of human activities. Because of the fact that these services were little understood they were not recognized adequately in land management practices or government policies. Thus, the mosaic of ecosystems, evolving under the direct action of the less polluted Danube waters, marine waters and the general factors of the climate, fell under the impact of human activity beginning with the 19th century.

2. Transformation and drivers of change in Danube Delta in 19th and 20th century

2.1 Hydro technical history changes of the Danube Delta. The Danube Delta complex, has suffered an important impact of human activity, both from inside and outside the area. The human major interventions started at the end of 19th century when measures to improve the navigability of Sulina branch were taken - shortening and deepening were carried out between 1862 and 1902, for marine navigation (Table 1). By this works, maritime ships got access to upstream ports such as Galati and Braila.

Table 1 The main corrections made to the Danube branches

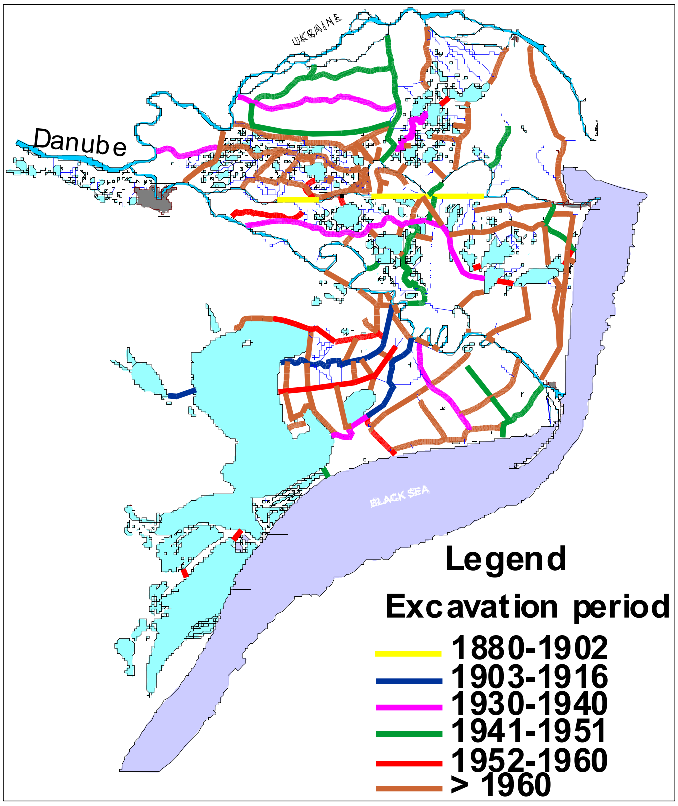
Danube's branch name	Length (km)			Width mean (m)	Slope at mean level (%)	Anfractuosity's coefficient	
	1870	1983	corrected			Natural regime	After corrections
Chilia	113.0	120.0	-	340	0.015	1.6495	-
Tulcea	19.6	17.5	-	296	0.022	1.3725	-
Sulina	91.9	63.7	-	146	-	1.0241	-
Sf.Gheorghe	104.9	108.2	69.7	348	0.017	1.6590	1.0689

Source: Danube Delta Biosphere Reserve Atlas, 2006

Already at the beginning of the 20th century, but specifically the last decade, many canals were dredged in the interior of the delta, with the purpose to increase fish production and to improve transport (Figure 6). Thus were cut the Dranov and Dunavat canals after the studies and designs of Prof. Grigore Antipa. The idea was to supply fresh water to the Razim-Sinoe lake complex.

In the 1920-1940 several more canals diggings (Litcov-Caraorman, Sireasa, Pardina and others) were aimed at facilitating inland, economic reasons, with a total disregard for ecological requirements, which created a very dense drainage network to supply fish-farms, agricultural terrains, reed and forest exploitations. Many canals (e.g. Crisan-Caraorman, Sonda, Mila 35) have completely disturbed the natural water circulation system, with severe consequences for the entire normal evolution of the area.

Figure 6 Hydro-technical history of the Danube Delta



2.2 Social organization of resource management in the Danube Delta during the communist regime

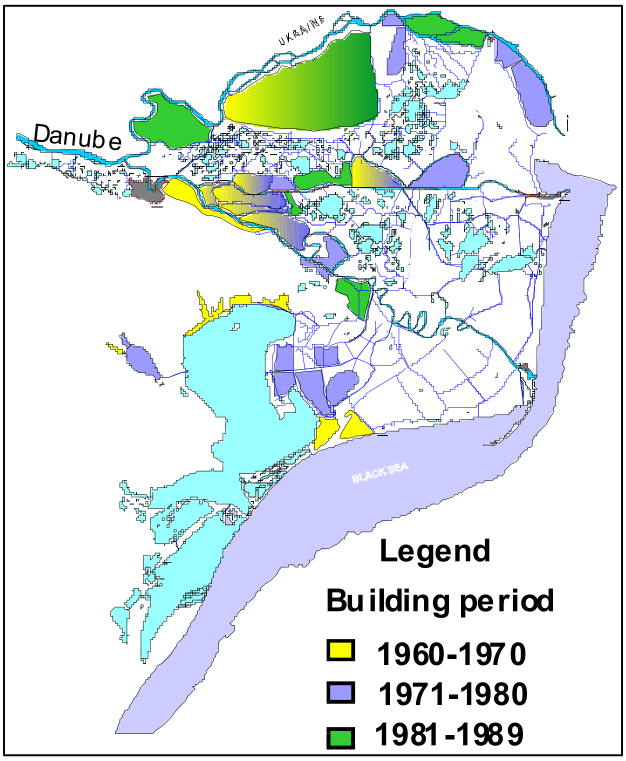
The man-made geographic changes the inside Danube Delta are mainly consequences of different land-use policies promoted in the last half of the 20th century – during the former communist regime.

In the last decade of the communist regime, the Danube Delta was administered by the state-owned consortium *Centrala Delta Dunarii*, which pursued the complex exploitation of the Delta resources. The *Centrala* included circa 20 enterprises involved in multiple activities (fishing, agriculture, reed harvesting etc), each of them in control of a Delta area.

Thus, for the 1960-1970 period, in order to increase reed production, an intensive campaign of works started. In this so called **"reed period"**, first large areas have been dammed to regulate and optimize the water level – as the key factor for reed beds development. Beside this, channels were cut in order to facilitate reed harvesting and transport to a cellulose factory especially built upstream, near Braila.

Between 1970-1980 years, known as the **"fish period",** many areas were embanked, and leveled to be used for commercial fish-farming. These fish ponds were supported by electrical pumps and almost free electricity allowing water to be pumped in and out of the polders as the aqua farm management deemed fit. The decade 1980-1989 **"the agriculture period"**, marks an explosive extension of agricultural polders - Pardina, 27.000 ha; Sireasa, 7.500 ha (Figure 7).

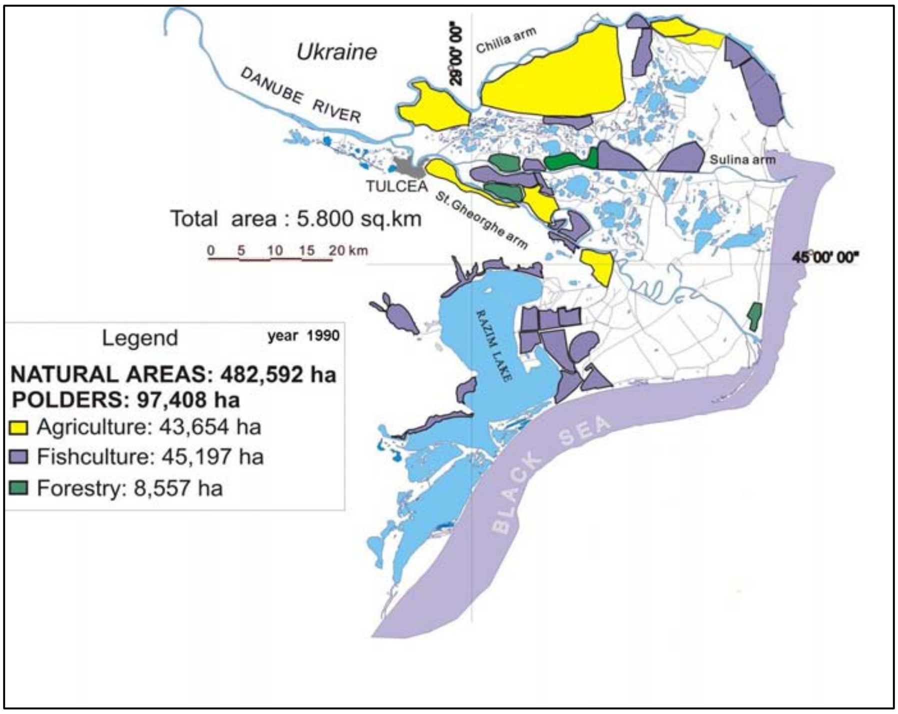
Figure 7 The building period within DDBR



All these human interventions considerably modified the local landscape and influenced the functioning of the delta ecosystem. The dammed areas increased from 24,000 ha to more than 97,000 ha and have been cut off from the Danube river pulse system (Staras, 2001).

When the works were stopped early 1990 after political changes in Romania, the dyked area of the Danube Delta comprised 97,408 ha out of which 39,974 ha were dedicated to agriculture use (Figure 8). These negative effects were amplified by the hydro technical works which destroyed about 400,000 ha of flooding area upstream (Baboianu, 2002).

Figure 8 The distribution of the anthropogenic polders within Danube Delta, in 1990 year



After 1990, the agricultural polders were used even less, due to the negative cost-benefit balance and the dry climate in the area.

The greater part of the fishponds is not suitable for the purpose they initially were designed for, because of the organic bottom layers. The productivity is low and the technological costs are high, due to the electricity costs for pumping water (Staras, 2001). All in all the economic down turn resulted in large scale unemployment, which increased pressure on the DDBR resources as people turned to them to make ends meet.

2.3 The effects of management practices registered for the Danube Delta Complex

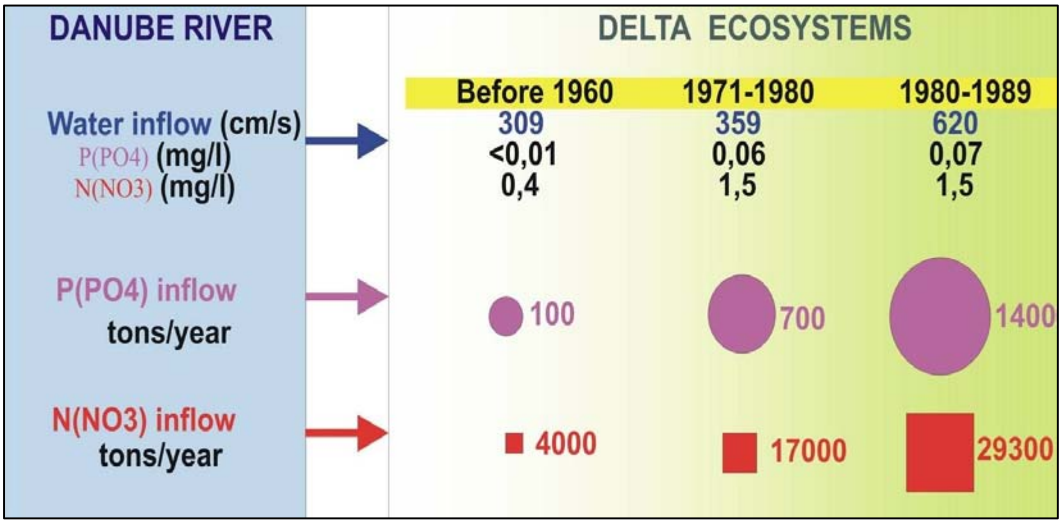
- Cutting an extensive channels system

For Danube Delta, the result of hydro-technical works for economic purposes consisted in increasing of the total length of the channels from 1743 km to 3496 km (Gastescu and Driga, 1983).

The discharge of the Danube river to Danube Delta's wetlands increased also from 167 m3/s(before 1900) to 309 m3/s(1921-1950), 359m3/s(1971-1980) up to 620m3/s in 1980-1989 period (Bondar, 1994).

The siltation of the natural lakes directly connected to the river accelerated and the nutrients inflow increased even more than the discharge due to increasing pollution of the Danube River (Figure 9) (Staras, 2002).

Figure 9 Changes in water and nutrients exchange between river and floodplain



Source: DDNI

By this, the equilibrium between plankton-benthos-fish fauna got lost, the algal blooms (Cyanobacteria) becoming cronical phenomena during summer time, and controlling many other biological processes (Baboianu, 2002).

- Building dykes for reed exploitation and polders for agriculture, fishfarming and forests

By the above mentioned works, the wetland's natural functions were dramatically affected:

- hydrological function :
  - the water balance was changed as well as the exchange of water between the remaining ecosystems
  - the water storage capacity was diminished

- biogeochemical function:

- the role as biological filter for the water discharging into the Black Sea was reduced
- ecological function :
  - many natural habitats for plant and animal species were reduced and partly destroyed

Other important effect of the period mentioned above is the decrease number of lakes within the Danube Delta. In 1964, in the Danube Delta were 661 lakes of over one hectare, totaling 31.262 ha (9, 49% of the delta area). Draining and damming works in the Pardina and Sireasa agricultural sub-units left only 479 lakes and 25.794 ha, that is 8.06% of the delta area (Table 2). A number of 120 lakes (3660 ha) in Pardina and 40 lakes in Sireasa (600 ha) were drained.

Table 2 The Danube Delta's lakes situation before and after 1960 year

Unity name	before 1960				after 1960			
	number	%	Area (ha)	%	number	%	Area (ha)	%
Chilia-Sulina	396	59	15,084	48	214	45	9,464	37
Sulina-Sfântu Gheorghe	178	27	12,7	41	175	36	12,802	50
Dranov	94	14	3,478	11	90	19	3,4	13
Total	**661**	**100**	**31,262**	**100**	**479**	**100**	**25,794**	**100**

Source: Danube Delta Biosphere Reserve Atlas, 2006

2.4 The Conservationist policies

Almost immediately after the fall of the communist regime in December 1989, the Danube Delta was declared a Biosphere Reserve, and the activities of land reclamation ceased. Shortly afterwards the DDBR was listed on the Man and Biosphere Programme - UNESCO, and it was placed on the List of the World Cultural and Natural Heritage. In 1991 Romania signed the RAMSAR convention that lists DDBR as a wetland of international value.

The Danube Delta Biosphere Reserve Administration (DDBRA) was established in 1993, and its structure and attributions were defined in 1994 by Government Decision 248/1994. The Decision stipulates that *"The mission of the Reserve Administration consists in creating and applying a special regime of management in order to conserve and protect the biodiversity in the natural ecosystems of the reserve, to develop human settlements and to organize economic activities in correlation with the support capacity of these ecosystems"* (Article 5).

In 1996 the Government established a plan of measures to promote the development of the DDBR area, by which residents of the DDBR are granted several facilities, including the right to family fishing, tax deductions, wage increases for specialists employed in the Delta (teachers, doctors, civil servants), subventions for transportation, electricity, heating, gas and water.

In 1997 the Government and the DDBRA initiate a regulation plan for fishing activities, requiring individual permits for all professional fishermen. Fishing is further regulated by the Law of Fishing and Aquaculture in 2001. In 2002 the Government decides the concession of fishing and reed collection activities in the DDBR.

The DDBRA establishes sustainable harvest levels (quotas) for commercial species of fish, based primarily on reported capture levels from the previous year. According to DDBRA information, in the period 1995 – 2004 the sustainable fishing quotas have not exceeded 6000 tons/year. In 2003 the total quota was 4967 tons and in 2004 it decreased to 4000 tons (due to the difficult hydrological conditions of the previous year). During the last ten years the total quotas for the Delta waters have never been officially exceeded; reported captures have oscillated around 50% of the quota. Nevertheless, given the illegal captures delivered on the black market and the persistent underreporting, it is difficult to estimate the actual capture levels.

3. Basic accounts

3.1 Land cover accounts. For the period 1990-2000, the changes for the land cover categories produced on 0.16 % (910 ha) from the total surface of DDBR. The main categories which have changed from 1990 to 2000 are: the arable land which were transformed into urban areas and the shrub lands that became woodlands, as shown in the table below:

Tabel 3. Analyse of stock diversity account, using Corine Land Cover

	ID poligon	Cod 1990	Explication '90	Cod 2000	Explication '00	Surface area (ha)	(%) from Total area of Danube Delta
1	V-Tulcea 3 p	211	Non-irrigated Arable Land	112	Urban Areas	1.438	0.0002
2	V-Tulcea 1 p	211	Non-irrigated Arable Land	133	Construction Site	7.341	0.0013
3	E-Tulcea 3 p	411	Inland Marshes	121	Industrial or Commercial Units	11.021	0.0019
4	SV-A.A.Sireasa 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	37.983	0.0065
5	NE-Pardina 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	66.206	0.0114
6	S-A.A. Pardina 1 p	211	Non-irrigated Arable Land	411	Inland Marshes	133.737	0.0231
7	NE-Partizani 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	44.045	0.0076
8	A.S. Papadia 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	119.975	0.0207
9	A.S. Papadia 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	26.289	0.0045
10	NE-A.S. Papadia 1 p	311	Broad Leaved Forest	324	Transitional woodland-shrub	165.721	0.0286
11	ESE-Baltenii de Jos 1 p	324	Transitional woodland-shrub	311	Broad Leaved Forest	115.132	0.0199
12	Uzlina	231	Pastures	142	Sport and Leisure Facilities	38.664	0.0067
13	NE-D. Tasburun 1 p	211	Non-irrigated Arable Land	231	Pastures	3.632	0.0006
14	SSV-RBDD 1 p	411	Inland Marshes	211	Non-irrigated Arable Land	117.051	0.0202
15	SSV-RBDD 1 p	411	Inland Marshes	211	Non-irrigated Arable Land	17.025	0.0029
16	S-RBDD 2 p	231	Pastures	121	Industrial or Commercial Units	5.499	0.0009
	TOTAL					**910.759**	**0.157**

Source: Corine Land Cover

3.2 Water accounts. The predominance of the aquatic environment in the Danube Delta is due to the high discharge of Water River at the Delta junction (first bifurcation). During the period 1921-1990, the average annual water discharge was 6.570 m^3/s at the Delta entrance. The water discharge flowing through the Delta increased gradually from 260 m3/s between 1951 and 1960 to 620 m3/s in the 1981-1990 period (Bondar, 1994).

The seasonal variation of water discharge shows a wintertime minimum (with a small range in amplitude) followed by a significant maximum in summertime and another minimum in autumn. The summertime maximum represents 33% of the annual water discharge while the autumn minimum (which corresponds to the period of highly polluted water) represents only 17-18% of the annual water discharge.

The damming of large areas inside the Delta and the dense network of canals has led to a "quasi-canalisation" of the water flow, which is directed rapidly towards the eastern part of the Delta and out into the Black Sea, with negative effects on soils and ecosystems. In the 1921-1960 period the amount of alluvia carried by the Danube at the Delta entrance was about 67.5 million tons/year (2138 kg/s). In the last few decades, especially after building of the Iron Gates dams, the average annual suspended sediment discharge decreased significantly from 41.3 million tons in the 1971-1980 period, to 29.2 million tons between 1981-1990 (Bondar, 1970).

The salt content and the chemical composition have a small range of variation. Between 1946 and 1990 the total salt content shows a slow but continuous increase from 290 mg/l in 1960-1970 to 350 mg/l in 1971-1980 and 400 mg/l 1980-1990. The increase is due to chloride and sulphate anions and sodium and magnesium cations. The Danube provides mostly chlorides and sulphates as sources of salts for ground-water and soils. The main pollutants introduced by the Danube are nitrogen and phosphorus components.

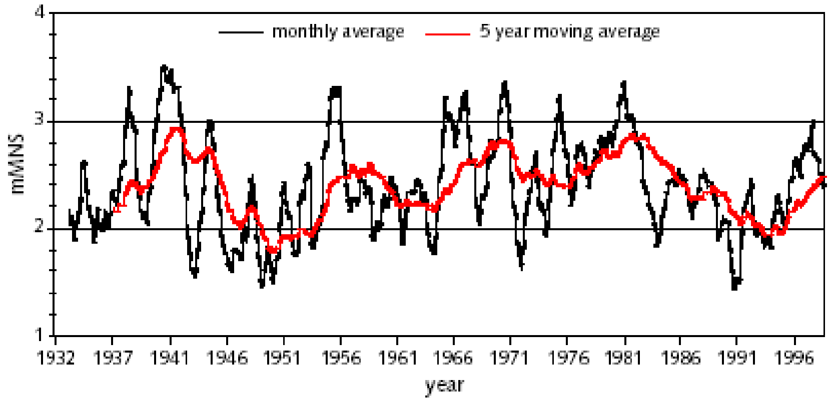
Water Levels of Danube River.

The water levels of the Danube have been measured for more than one century. In figure 10 the monthly averages of the levels are given for the period 1932-1998, in meter relative to the Black Sea Level at Sulina (mMNS).

The red line indicates the five year moving average, which highlights the long term changes. The levels show a long term variation with higher levels in the thirties and the seventies and lower levels in the fifties and the nineties.

The influences of the upstream canalization works or the construction of the Iron Gates dam in the upper Danube are not clearly visible in these data. The canalization works in the delta have a local influence in the delta, but barely influence the upstream levels in Tulcea. Within the year was observed a seasonal variation with a clear maximum in April through June, a minimum in September through November and a small peak in December through January.

Figure 10 Water levels of the Danube river at Tulcea from 1932 to 1998

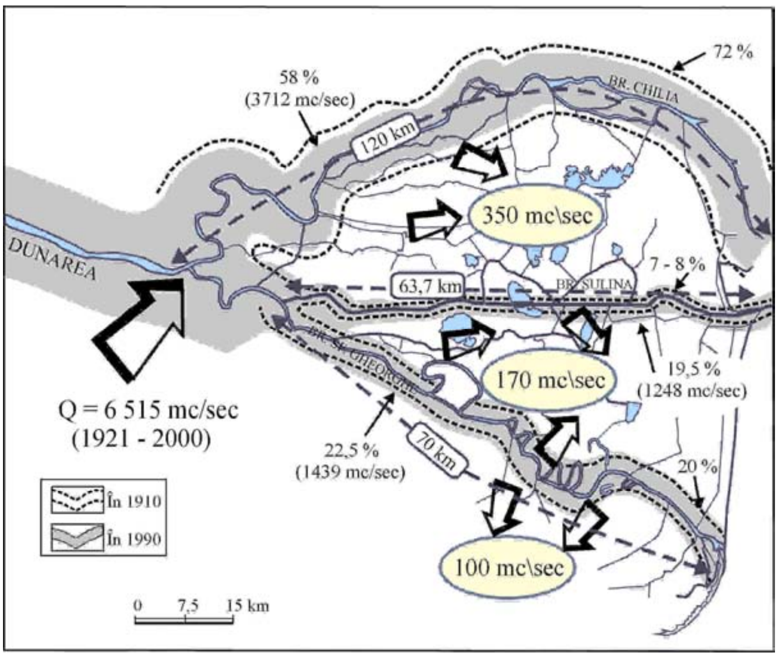


The discharge of Danube River

The **Chilia Branch** (120km long at Ceatalul Chiliei) has been and still is the most important as regards the flow. Up to 1890 it was characterized by a growing tendency of the flow and after 1910, when it used to transport 72% of the river flow at Ceatalul Chiliei, it has registered a decreasing tendency (63.8% in 1950, 63% in 1960, 60.8% in 1970, 59.1% in 1980 and 58% in 1980).

During the same period the **Tulcea branch** (being 17km lomg between Ceatalul Chiliei and Ceatalul Sfantu Gheorghe) registered a flow growth from 28% to 42.4% in 1990, not only because of the **Sfantu Gheorghe Branch** (109km long – at present 70km, having the highest meandering coefficient – 1.7) whose flow grew relatively – little over 19-20%, but chiefly owing to the **Sulina Branch** (63.7km long, plus about 8km – its extension into the sea with the side dams) which grew from 7-8% at the end of the 19th century to aprox. 20% at present, as a result of its continuous adjusting and draining (Figure 11 Tabel 4).

Figure 11 Distribution of discharge on the Chilia, Sulina and Sfantu Gheorghe branches



The Danube Delta liability to inundation – as a regulation service

The achievement of the delta liability to inundation is conditioned, mainly, by its hypsometric characteristics, amplitude and periodicity of reaching the maximum levels of the Danube as well as the restriction of the surfaces liable to inundation as a result of some damming processes.

Before the execution of the arranging and damming actions, in 1956, the real water supplying of the inner zones would begin when the Danube levels were higher than 3 hydrodegrees (about 150-160cm –Black Sea level (B.S.l.) at Tulcea); up to this level the inner lakes would communicate very little among them by the streams and canals network. The water supplying and circulation used to intensify once with the water level rising from hydrodegree 3 to hydrodegree 7; from 7-7.5 hydrodegrees upward (that is a level of 350-375cm B.S.I. at Tulcea) the Danube waters used to overflow the longitudinal river sand banks. Thus, the inner delta inundation process was generalized. When the Danube level used to exceed 8.5 hydrodegrees (about 425cm B.S.I.at Tulcea), the non-dammed longitudinal river sand banks were completely flooded, the level in the inner delta being the same with the level in the branches.

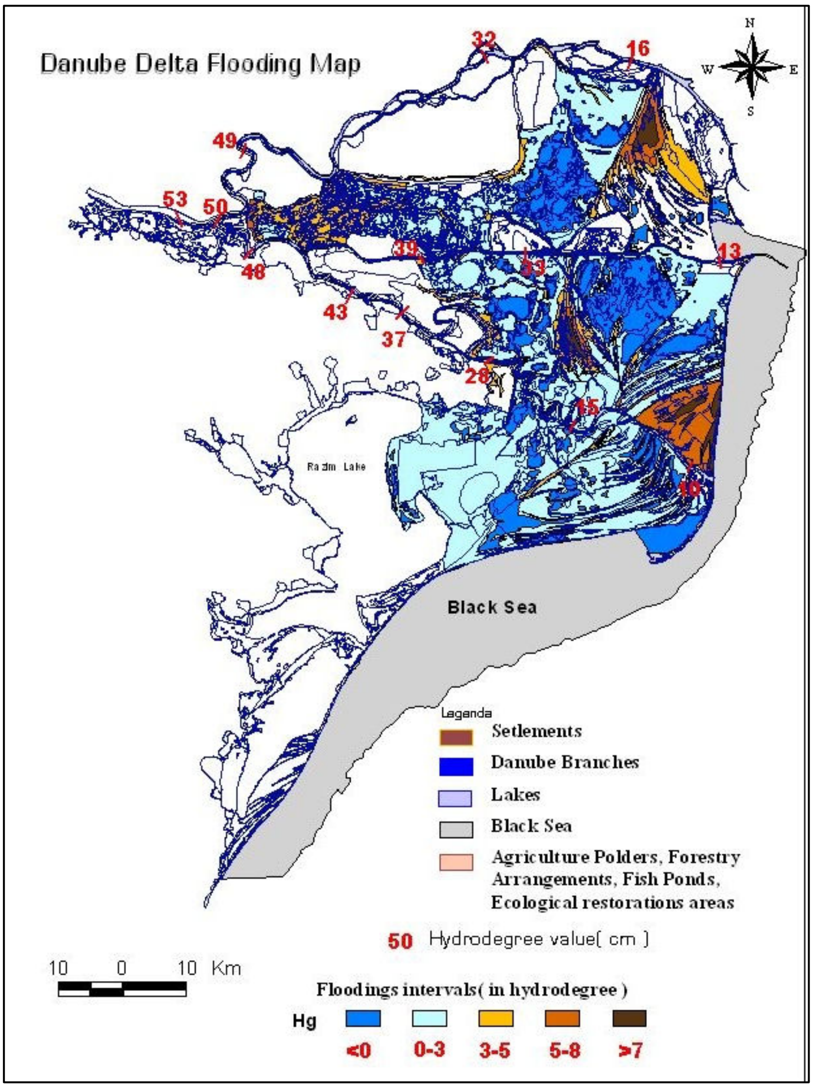
When reaching over hydrodegree 9, the water level in the inner river-sea delta reach and even exceed the level in the Danube branches, overflowing conversely.

The present analysis of the delta liability to inundation becomes very complex because about 31.2% of the Danube Delta (100,000 ha) is dammed and is not subjected to floods.

The first map of the delta liability to inundation was drawn up between 1910-1911 by Eng. I. Vidrascu, on the basis of the hydrodegrees established for the Danube branches. It shows the isolines corresponding to hydrodegrees 3,5 and 7. Although theoretically and even practically valuable, the 1910-1911 map does not correspond to the present because of the natural and anthropic changes afterwards.

The present map (Figure 12) of the Danube Delta liability to inundation was based on the hypsometric situation presented on the 1:50,000 scale map elaborated by the Geographical Institute (1983), and also on the statistic working out of the level data. Between the possibilities of analysing the liability to inundation either on the basis of levels at different ensurances or on the basis of hydrodegrees, the latter one has been chosen.

Figure 12 Danube Delta Flooding map



At 6 hydrodegrees, in non-arranged conditions, 83% of the Danube Delta (275,265ha) was covered by waters, thus ensuring 4,332mil.m^3 stored water.

The hydrograde 7-7.5 usually corresponds to the average of the maximum values of big waters (350-375cm B.S.I. at Tulcea); the reaching and exceeding these values mark the beginning of the surface flooding process in the entire delta.

At 10 hydrodegrees, the delta area is flooded 93.4% (309.470ha), the accumulated water volume being 6.2 billion m^3. The highest areas are not flooded: sand banks Letea, Caraorman, Stipoc and rarely Saraturile and Campul Chiliei; in the Dranov unit only 0.3% (961ha) remains uncovered by waters.

The fact that about 103,000ha of mostly low altitude surfaces were kept from the food effects has caused the reduction of the stored water volume with 30% (1,860 mil.m^3). Under such conditions a bigger Danube water quantity is transported in the delta space left in free regime, owing to the fulfillment of two conditions: the rising of the flowing speed (with benefic effects over water renewal, and with negative ones – alluvial and erosion growth) and the rising of the inner delta water levels.

3.3 Species accounts

The main reason for which the Danube Delta has become a biosphere reserve was that, in comparison with other deltas of Europe and even of the Earth, it has preserved, a higher biodiversity, that is a greater number of species in a bigger diversity of systematic units, beginning from the inferior plants (unicellular) to the superior ones (cormophyte), from the unicellular animals (protozoa) to the most-evolved vertebrates (mammals). Moreover, the DDBR strikes by the high density of samples of many species, which nowadays are rare or are missing from other parts of the continent, although some plants and animals species have become rarer or extinct, owing to some anthropic influences in the last decades, such as water pollution, change of natural areas into forestry, piscicultural and farming areas etc.

A number of over 5000 flora and fauna species was identified within 1991-1995 by means of researches performed thoroughly and systematically by a complex team that reunited specialists throughout the country.
As result of periodical and systematical registering of the main habitat and ecosystem types from DDBR, there have been observed new species too, for DDBR territory, for our country and even for science. 617 (11, 18%) from the total identified species within DDBR territory are new species for the Danube Delta, 133 (2, 39%) are new species for Romania and 26 (0, 41%) are new for science.

Regarding the ornitophauna DDBR comprises 325 species, 160 of them nestle into the Danube Delta, the favorite place for the ones which visit it every season, being a halt place for the migratory birds (Figure 13), situated of the middle distance between the arctic and tropical regions.
The Danube Delta is the place where cross more migratory bird ways, which go in the spring towards the North and in the autumn towards the South, choosing instinctively, the ways named in the past: Pontic and Sarmation of the Black Sea, East-Elbian and Carpathian adjacent to the Danube Delta.

Figure 13 Bird migration routes

The birds' population dynamics depends on a large number of biotic and abiotic factors. Within those abiotic, major importance have the hydrological, meteorological and pedoclimatological factors, but also land use patterns, hunting, cropping. In this way we emphasize the situation of some significant nesting colonies of birds species, as follows:

Figure 14 The dynamic of some significant nesting colonies of birds from fluvial delta, 1999 – 2006 period

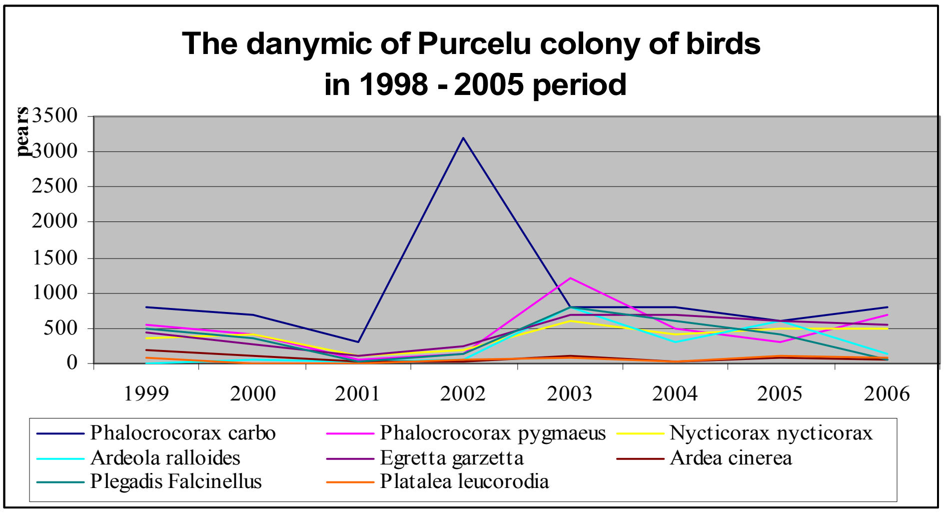


Figure 15

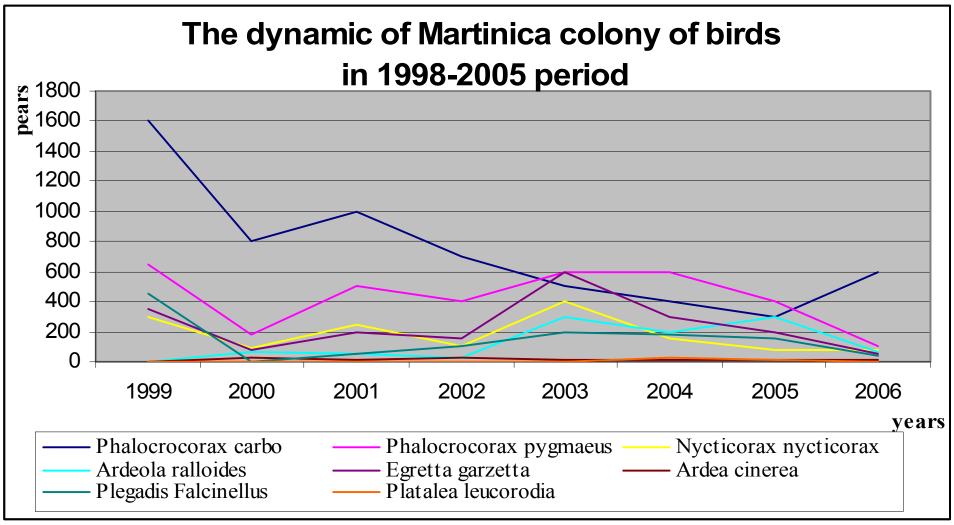
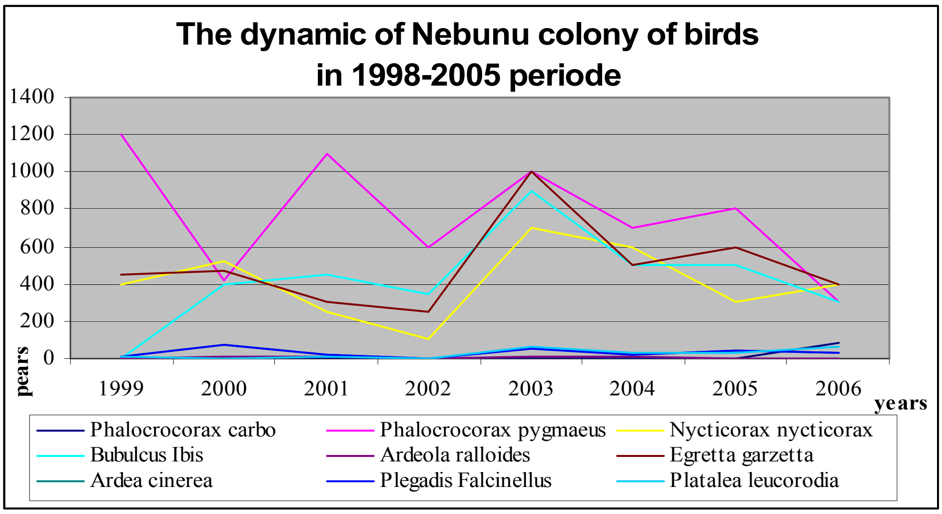


Figure 16



Source: DDNI data

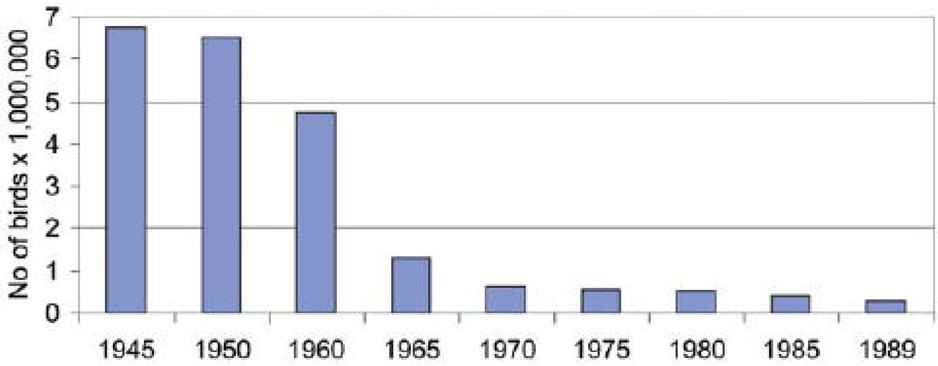
The decrease in species for the last three years (2004, 2005, and 2006) may be also the effect of human interventions in environmental conditions, through different activities, such as: dams, vegetation arsons and inadequate cuttings, intensive fishery, but also unorganized tourism and hunting. Alarming is that the forecasts for the next couple of years show no ameliorative situations in the context in which the use of touristic resources will keep accelerate. (Kiss, 2007).

Numerical developments of water birds in relation to human activities

It is typical for wetland habitats that they show a quite considerable amount of dynamics in space and time. This does not only influence the suitability of feeding sites, as has been indicated above, but will also affect the suitability of colony sites. Changes in spatial patterns of habitats that may affect colony site suitability will take place in all parts of the Danube delta, but are particularly well noticeable in the coastal and lagoon systems, where the time scale of the changes is shorter than in the freshwater fluvial systems.

Without more specific data, Dragomir & Staras (1992) estimated an overall presence of waterbirds (including all piscivorous species) of no less than 7 million individuals by the end of the Second World War in 1945, while by 1989 these numbers had gone down to no more than 0.3 million (Figure 17). Although, this decline would seem to be unbelievably strong, there is good documentation of the fact that, at times, quite impressive numbers of fish-eating birds, have been killed (*e.g.* in 1956 and 1957 totals of 106,340 and 70,000 respectively; Paspaleva *et al.* 1985).

Figure 17 Estimated numerical development of water birds in the Danube Delta between 1945 and 1989, according to Dragomir & Staras (1997).



Land-use and water management - cause for habitat loss/fragmentation of waterbirds species

Up to the present day, **agricultural land-use** has had an important impact on the ecological functioning of the Danube Delta. Significant parts have been reclaimed for agricultural use and have thus reduced the surface area of natural wetlands. The largest polder reclaimed is the Pardina polder in the northwestern part of the Romanian Danube Delta Biosphere Reserve. Without doubt, the reclamation of this area has led to a decrease in both potential feeding habitats and suitable breeding sites for most of the colonial waterbird species. The only exception is likely to be the Cattle Egret, which is by far the most terrestrial feeding species and probably even became established as a breeding bird due to this reclamation.

Another type of land-use, which has been practiced in the past, consists of the construction of **artificial fishponds**. This artificial habitat, however, is likely to have become included in the feeding areas of most colonial bird species. Moreover, these practises have proved to be uneconomical, because of the difficulty of regularly draining and refilling the ponds. By and large, nowadays all former fishponds have been abandoned and are, once again, completely incorporated into the delta's natural ecosystem. An exception is the fishpond area at Rusca Balteni, where a large Purple Heron colony was still established in 2001 (pers. comm. Paul Cîrpaveche), but was reclaimed for agricultural purposes in autumn of the same year. This inevitably resulted in the disappearance of this colony.

The main human impact on the Danube delta has undoubtedly been the **design, construction and maintenance of waterways for navigation infrastructure**, facilitating activities such as fishing and Reed harvesting. This has led in the past to a vast network of canals, connecting the lakes among themselves and with the main river branches. As has been shown above, this system of canals and its enhancement of the connectivity of many of the larger lakes have probably led to higher standing stocks of fish in the lakes. Both man and piscivorous birds may have taken benefit from these changes. On the other hand, water quality gradients are likely to have changed in favour of the more eutrophic situations, reducing the amount of more isolated and more mesotrophic freshwater lakes that are likely to have characterised the more pristine situation (*e.g.* Oosterberg *et al.* 2000). Thus, although the larger piscivores like cormorants and pelicans may have profited from these man-induced changes, the smaller species of heron, the Pygmy Cormorant and the Glossy Ibis, feeding mainly on small (semi-)aquatic invertebrates, are likely to have suffered decreases.

History of birds and human impact

1) **The end of the XIXe century and first half of the XXe century**

By the end of the 20th century, very large numbers of breeding gulls and terns were present in the Romanian Danube delta (Table 4). Moreover, six species absent in the 2001-2002 censuses were still noted as breeders:

Table 4

Species	End of the 19th century	Beginning of the 20th century	Main sites
Pontic Gull	Thousands	Largely smaller numbers	Razim and Sinoe lagoon
Lesser Black-backed Gull	Small numbers until 1922-1923		Snakes island
Slender-billed Gull	Thousands	Hundreds	Sinoe lagoon
		Some colonies (1930)	Grindul Chituc
		3 nests	Near Istria
Mediterranean Gull	Thousands	800-1000 pairs	Razim and Sinoe lagoon
Black-headed Gull	Large numbers		all lakes of the Danube delta
Little Gull	Small numbers	Unknown	Dobrodja area
Gull-billed Tern	Thousands	Unknown	Razim area
Sandwich Tern	Thousands	One small colony	Sinoe lagoon
Caspian Tern	Thousands	Largely smaller numbers	Razim and Sinoe lagoon
Common Tern	Thousands		Razim and freshwater of the delta
Little Tern	Breeding	Breeding	Razim and Sinoe lagoon

Source: DDNI

Lesser Black-backed Gull *Larus fuscus*, Slender-billed Gull *Larus genei*, Little Gull *Larus minutus*, Gull-billed Tern *Gelochelidon nilotica*, Sandwich Tern *Sterna sandvicensis* and Caspian Tern *Sterna caspia*. Some observations may be considered suspicious, such as the breeding of the Lesser Black-backed Gull in regard to their present-day distribution area in Central Europe. Moreover, the presence of the Little Gull was not precisely located (i.e. in the Dobrodja area) and the species may not have bred within the delta area.

As observed today, the Razim lagoon complex was the main nesting area of most the species. However, an important decline was observed during the first half of the 20th century for at least Pontic, Slender-billed and Mediterranean Gull and Gull-billed, Sandwich and Caspian Tern. In addition to the habitat changes expressed above, this period is also characterised by the canal construction on Sulina branch (1874-1902) with the help of numerous manual workers. Moreover, at the beginning of the 20th century, the railroad arrived in Tulcea and numbers of people living in the delta may have increased accordingly. Thus, this period may also be seen as one of an increase of human presence and disturbance in the delta.

2) **The 1950' and 1960' period**

The breeding area of the Black-winged Stilt was restricted to the salt marshes and lagoons of the Romanian Danube delta. In the salt marshes of Murighiol, the presence of 30 - 60 nesting pairs justified the designation of this area as special refuge for the species in 1960-65. However, numbers were highly variable and only a single pair bred in 1966 due to high water level, whereas three more pairs bred along lake Plopu. The impact of water level variation on these species in Murighiol and Plopu was also noted in 2001-2002. Several pairs bred in the Razim complex and in the mid-southeast of the Danube delta where they nested on small plaurs and old *Juncus* spp. ramets.

3) **The 1970'-1990' period**

The main change observed since 1968 is the first breeding of colonial Charadriiformes on Sachalin peninsula (Table 5). There, 10-12 pairs of Collared Pratincole were counted and one dead chick of Gull-billed Tern was found. The most abundant species was the Common Tern nesting along 2.5-3 km along the beach. About 15,000 pairs were estimated to be present. Between 100 and 200 pairs of Little Tern were counted and Sandwich Terns were present. Between 1969 and 1971, numbers were more or less similar and five pairs of Pied Avocet bred. Between 1972 and 1974, the Black-headed Gull was controlled for the first time (1972) and numbers of Sandwich Tern increased (31 nests in 1972, over 300 in 1973 and 2500 pairs in 1974). Numbers of Common Tern and Little Tern were stable.

Table 5 Development of breeding pair numbers of colonial Charadriiformes on the Sacalin peninsula during the period 1968-1990.

Species	1968	1969-71	1972-1974	1980	1990
Pontic Gull	0	0	0	0	278+
Black-headed Gull	0	0	20	Several	0
Common Tern	15,000	10,000	15,000	2000	0
Little Tern	100-200	100-200	100-200	100-200	0
Sandwich Tern	Present	Unknown	2500	1000	0
Gull-billed Tern	1+	0	0	0	0
Collared Pratincole	10-12	2-3	0	0	0
Pied Avocet	0	5	0	0	0

Source: DDNI

In 1980, numbers of Common Tern decreased a lot whereas the other species were still present. In 1990, all these species did not breed anymore and were re-emplaced by the Pontic Gull (278 chicks were ringed).

The quite well documented development of the colonies in the Sachalin peninsula is representative of the combination of human intervention and human management and of their resulting effects on the lack of natural breeding sites.

The huge colonisation of Sachalin at the beginning of the 1970s resulted from the natural formation of the peninsula and its disconnection from the mainland. It was the most important Charadriiformes area of the Romanian Danube delta and the last site used by Sandwich and Gull-billed Tern, two species which disappeared from the area since the 1990s. Today, the peninsula is directly connected to the mainland and frequently visited by people. Both human disturbance and predation by mammals may explain by themselves the absence of breeding birds in 2001 and 2002.

4. The population issue

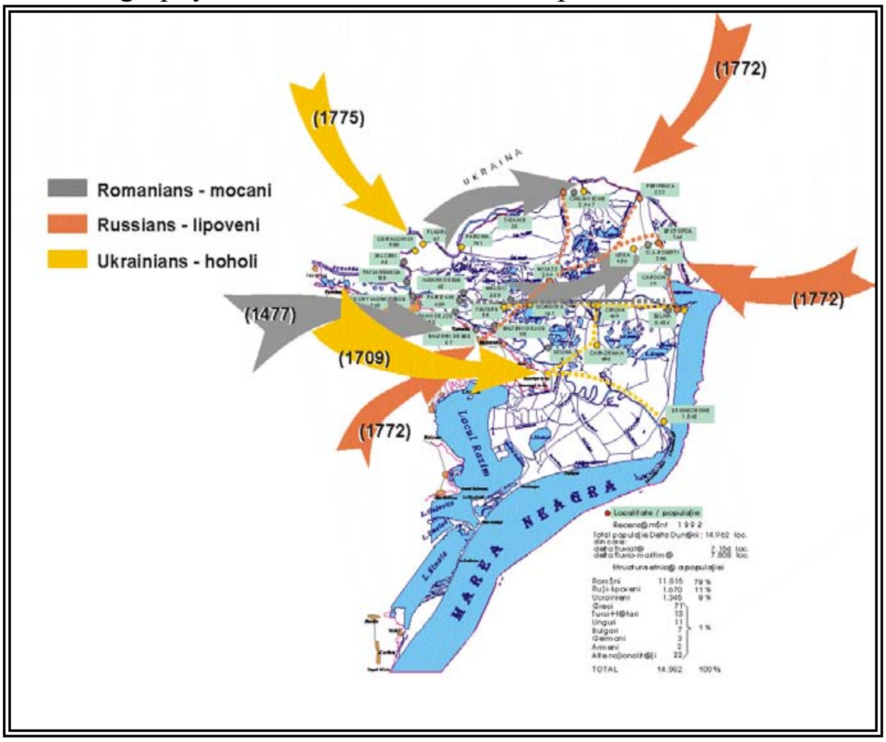
4.1 History of human settlements in Danube Delta

The first signs of human settlements discovered in delta date from before the Middle Ages and even as far back as the Neolithic age - witnessed by the ruins of ancient Greek cities of Histria and Argamnum built on the western side of the present-day Razim-Sinoe lagoon complex in the 6th-5th centuries BC. In the Byzantine period, starting in the 10th century several settlements developed, including the present-day town of Sulina.

During the Turkish Empire, which started at the beginning of the 15th century, some new settlements – e.g. Caraorman - were established. The majority of the population of the delta were Romanians, during the period of the Ottoman Empire. They grew crops, vines, bred cattle and were fishermen. During the 18th Century, the population in and around the delta was added to by Ukrainians and Lippovan Russians. The latter were driven out by some doctrinal schisms within the Russian Orthodox Church. Lippovans are still numerous within and around the delta. A proportion of the Turkish and Moslem population also settled in the Dobrogea and some remained when the Turks were finally driven out at the end of the War of Independence (Figure 18).

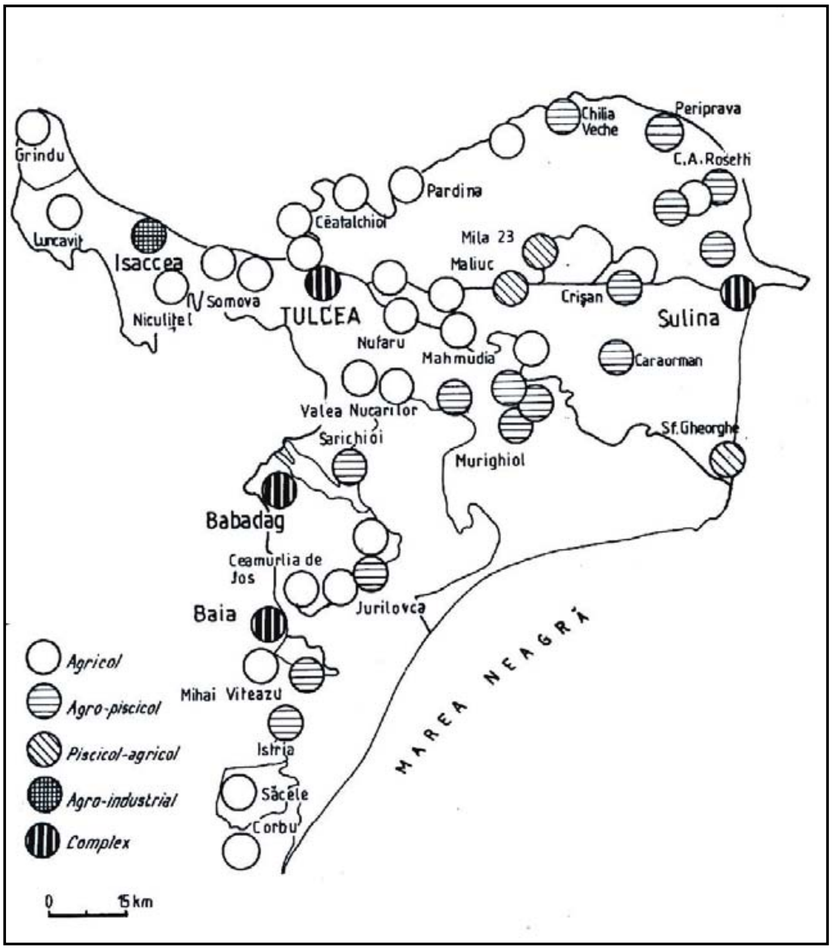
Following these events a range of a new towns were founded: Crisan 1877, Ilganii de Jos 1899, Patlageanca 1900, Vulturu 1918, which had to be added to the former ones: Pardina and Stistofca founded in the 18th century and C.A.Rosetti at the beginning of the 19th century.

Figure 18 Flow demography within Danube DeltaBbiosphere Reserve



The Danube Delta SES embeds 26 settlements that are divided into seven communes and one town (Sulina), summing 14 295 inhabitants.The largest village in each commune serves as centre for social services. Well-being and local economy in all these municipalities largely depend on the ecosystem services provided by the Danube Delta ecosystems. Thus were distinguished different functional types of settlements, as shown in the Figure 19:

Figure 19: Functional types of settlements



4.2 Trends in population

Hystrorically, the population of the Danube Delta fluctuated between 13 000 and 20 000 inhabitants, being strongly influenced by the two world wars, the development of the town Tulcea, and the Constanza harbor (Tabel 6). Periods of economic activity, like the „reed", fish farming and polder construction for farming, saw increases. By 1966 the population reached its maximum, with 19,700 inhabitants in the delta (down to 14,300 in the delta proper in 2002).

Many of the investments made during the communist period, in order to exploit the delta's resources did not work out and its people started to move to places like Tulcea to seek employment in the factories. Because migration took place mostly among young people below the age of 35 years, *the decline* in the population is associated with aging phenomena. Since then the delta population has continued to decline until 1997. After this year, because of the unemployment trands at national level, a part of delta's inhabitants returned to their origin villages. For this reason from 1997 to 2002, the rural population increased with 22‰

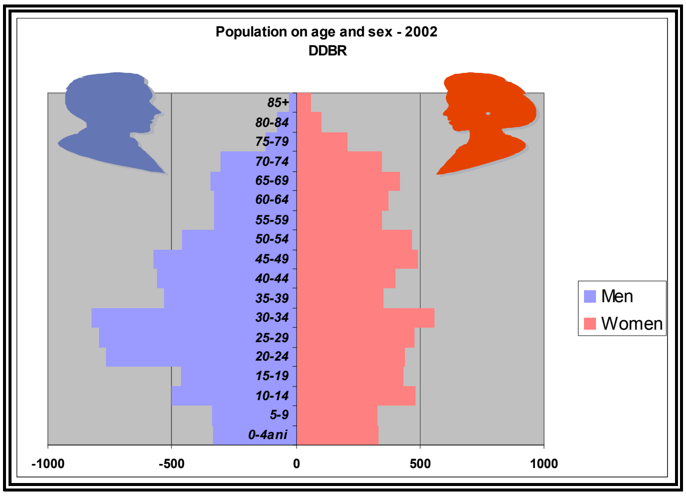
Tabel 6 The evolution of the Danube Delta population (census data)

Years	1912	1930	1966	1977	1992	1997	2002
Urban	**7 347**	**6 399**	**4 005**	**4 911**	**5 484**	**5 137**	**4 601**
Rural	**10 459**	**12 135**	**15 713**	**11 695**	**9 046**	**8 475**	**9 694**
Total	17 806	18 534	19 718	16 606	14 530	13 612	14 295

Source: DDNI

The population is an ageing one (Figure 20) and younger people tend to move to the larger towns, so they can enjoy the benefits of modern society. Whilst the number of marriages is reducing, the number of funerals has almost doubled.

Figure 20 The age pyramid based on census data



The main ethnic groups in the DDBR are Ukrainians and Lipovani (Table 7).The official number of Ukrainians decreased dramatically between 1992 and 2002 years and is still decreasing Local respondents attributed this decrease to a trend of switching ethnic self-identification from 'Ukrainian' to 'Romanian', especially among the younger generations, who no longer speak Ukrainian and do not feel attached to the ethnic identity of their parents.

Table 7 Ethnic structure of population in Danube Delta according to census data

Ethnics	**Census 2002**
Romanians	12 396
Ucrainiens	287
Russian Lippovans	1 436

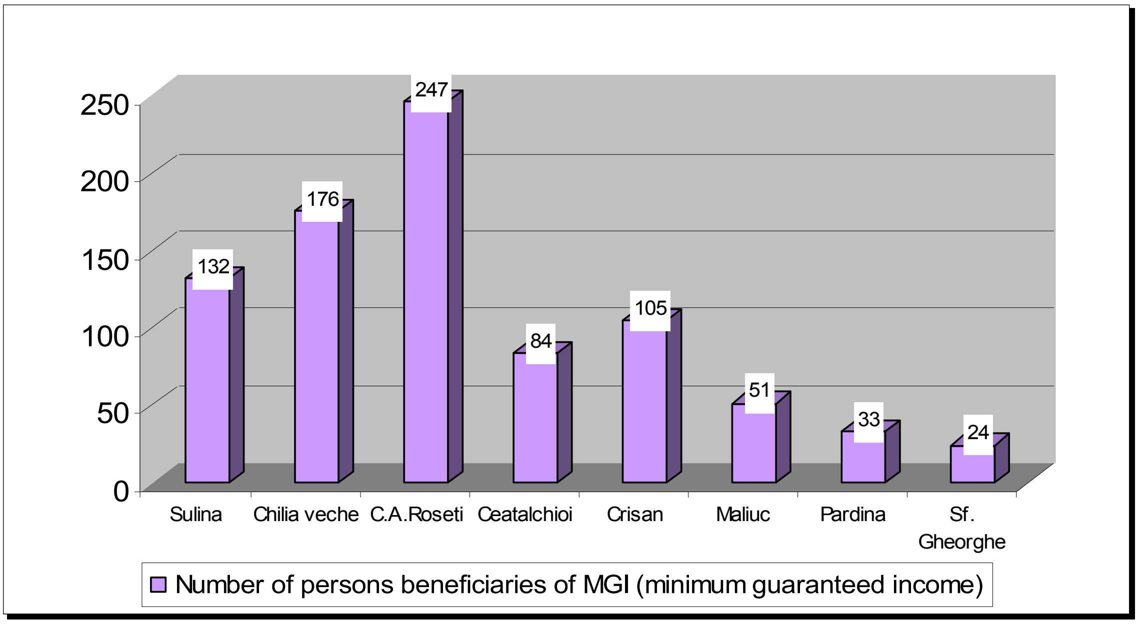
Ethnics	**Census 2002**
Greeks	63
Turks and Tatars	18
Bulgarians	1
Armenians	2
Germanics	2
Rroma	69
Jewish	1
Albanians	0
Italians	6
Hungarians	10
Polish	2
Other nationalities	3
Total	14 295

4. 3 Population aspects in Danube Delta

Using the data concerning the beneficiaries of two social supports (Law no. 416/2001 and Law 41/2002) it was estimated the number of people in difficulty (poverty) in Danube Delta. Among the all 7 comunas of The Danube Delta and Sulina town, the community from C.A.Roseti is considered to be endangered of extreme poverty (Figure 21). About 25 persons from 1000 have incomes under the limit of MGI (Minimum Guaranteed Income), being one of the poorest communities. The lack of the possibility to work in fishery like other local communities, the old age of the local people and the very low efficient agriculture are the main reasons of this situation.

The other localities in Danube Delta are not very poor. The main advantage of the local people is the access to several nature resources, including fish, reed, pastures.. Having in view their isolation there are some facilities to compensate the situation: subsidies for local transport, for electric energy, supplementary salary for the people working in the Danube Delta, the right to fish for familial consumption (Ana Dumitrescu, 2005).

Figure 32 Beneficiaries of MGI in Danube Delta (31.12.2004)



The **lack of jobs** in the Danube Delta is severe, and this situation provokes migration of the young people to other localities of the country abroad. On the beginning of 2005, very few working contracts were registered in the Directorate of Labor in Tulcea: 381 contracts in Sulina, 5 contracts in Ceatalchioi, 22 contracts in Sfantu Gheorghe. The Agency for Unemployment recorded only 107 paid unemploiers and 178 unpaid unemploiers (Ana Dumitrescu, 2005).

The most important difficulties are considered the access on education and culture of the younger people due to the isolation, and due to the lack of teachers as the access to the medical assistance, as well. Most of the localities have no more then 1 doctor (2 localities without) and other specialized people (table 8).

Table 8

Communities	**Education units**		**Number of students**		**Number of teachers**	
	Primary and general school	**High school**	**Primary and general school**	**High school**	**Primary and general school**	**High school**
Sulina town	-	1	444	393	28	12
C.A.Rosetti	3	-	107	-	9	-
Ceatalchioi	1	-	51	-	6	-
Chilia veche	1	-	280	-	15	-
Crisan	3	-	119	-	18	-
Maliuc	2	-	102	-	12	-
Pardina	1	-	51	-	6	-
Sfantu Gheorghe	1	-	80	-	9	-
Total Danube Delta	12	1	1234	393	103	12

If the localities closer to Tulcea municipalities (Ceatalchioi) can have an easier access in Tulcea hospital and private medical cabinets, in other localities this access is limited and they can benefit by the only hospital in Danube Delta in Sulina (Tabel 9). The equipment of hospital in Sulina is very poor, and many other locations are improvisations. Due to this situation, the health of the local people is affected by different diseases (Ana Dumitrescu, 2005).

Table 9 Health – public sector in Danube Delta communities, 2002

Communities	Number of beds in hospital	Doctors	Dentists	Pharmacists	Nurses	Number of Inhabitants per doctor
Sulina town	30	3	1	1	15	1574
C.A.Rosetti	-	1	-	-	1	1088
Ceatalchioi	-	-	-	-	1	-
Chilia veche	-	1	-	-	2	2585
Crisan	-	1	-	-	1	1391
Maliuc	-	1	-	-	1	1019
Pardina	-	-	-	-	-	-
Sfantu Gheorghe	-	1	-	-	1	947
Total Danube Delta	30	8	1	1	22	8604

Source: Census 2002,

4.4 Livelihoods and local needs

The Danube Delta SES embeds 26 settlements that are divided into seven communes and one town (Sulina), summing 14 295 inhabitants (Lomas et *al*., 2007).The largest village in each commune serves as centre for social services. Well-being and local economy in all these municipalities largely depend on the ecosystem services provided by the Danube Delta ecosystems. Since the ancient times, fishing has been the main occupation of the inhabitants of Danube Delta. Although today the supply of fish has diminished and changed in quality, this occupation continues to be a basic one. The second main occupation with great extension has been (and still is) sheep and cattle breeding, which from a temporary condition (being practiced by the shepards coming there with their flocks in wintertime from the eastern Carpathians and the Moldavian tableland), became a permanent occupation in the last decades.

a) Fishing

Fishing, both professionally and for subsistence use, is the single most important livelihoods activity in the DDBR. DDRBA data for the year 2004 indicate that 1375 professional fishing permits have been issued in the Delta. Also, almost all households living in the DDBR (except professional fishermen) have family fishing permits, for family consumption, to which they are entitled according to law (L 82/1993, HG 248/1994, OG 27/1996, L 192/2001). The Law 192/2001 is the first to limit family fishing to 3 kg day per household. In 2000 there were approximately 4500 family fishing permits (according to DDBRA). State-owned enterprises that employed fishermen until mid-90s also provided the fishermen with all necessary equipment. The collapse of these enterprises transferred the responsibility for buying and maintaining the fishing equipment (tools, boat, motor etc) to the fishermen, at considerable costs.

Many fishermen were not able to mobilize the necessary resources and felt they were thus gradually excluded from this income generating activity. The initial costs of equipment (estimated to about 50 million lei – US $ 1,500) also limits the entry of new fishermen. It is important to notice here that while legal tools (*setci*, *vintire*, *taliene*) are relatively expensive, illegal tools such as nylon nets (*setci monofilament*) are very cheap) and thus easily affordable for anybody.

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According to the interviewees, the profitability of fishing for the local fishermen decreased significantly after 2003 as a result of restrictions related to the introduction of the concession system. It is difficult to estimate average fishermen's incomes. Interviewees were elusive when the issue of income levels came up, stressing that incomes depend on month, equipment, weather and especially on luck. It has been also difficult to estimate average costs for fishermen and expenses while taxes and insurance payments are generally surrounded in uncertainty.

b) Agriculture

As in most rural areas, villagers depend on a number of income generating activities to make a living. Apart from fishing, agriculture is a major source of income in the DDBR. While some localities have access to significant agricultural resources, others have no other options (see Table 10).

Table 10 Economically active population in DDBR, according to the 2002 Census

Locality	Total unemployed population	Total employed population	Main employment in %			
			Fish aquaculture	Agriculture, silvi-culture	Public and social services	Other
Sulina	342	1516	11.1	1.4	23.6	63.9
C.A.Rosetti	12	757	7.9	76.2	6.5	9.4
Ceatalchioi	47	176	0.6	72.7	9.7	17.0
Chilia Veche	240	594	11.6	34.5	31.1	22.7
Crisan	144	318	47.8	5.0	17.0	30.2
Maliuc	81	245	18.4	30.2	16.7	34.7
Pardina	46	237	2.1	69.2	16.0	12.7
Sfantu Gheorghe	30	266	48.1	3.0	24.8	24.1
Total	942	4109	15.3	29.0	19.7	36.0

Source:

In the DDBR, agriculture provides essential resources for family subsistence, but it is a much poorer source of cash income than fishing. Animal husbandry is also practiced for subsistence needs, rather than for commercial purposes. Animals are often raised in the wild, even during winter, when they suffer high mortality rates.
The high costs of transportation are a major obstacle for commercial livestock production. Merchants come to buy cattle in the villages, but residents complain about the low prices and many prefer to keep the animals for their own consumption or undefined future needs.

Since travel costs are prohibitive for trade, the only possibility is to sell small quantities of products through relatives or acquaintances in town, sending them as a package on the boat. Occasionally one can slaughter a cow, divide it into portions and transport it to town (Sulina or Tulcea) to traditional customers.

Local needs

Delta villages suffer from isolation, as they are located within the delta tributaries and channels and from poor infrastructure facilities. The lack of road transportation to the neighboring towns of Tulcea and Sulina is widely considered a major obstacle in the development of the Delta localities. Villagers and local authorities deplore the expensive and slow naval transportation means. Transportation costs are borne by local people when they travel to town, but they are also reflected in local prices for all types of goods, including food, fodder, and construction materials. Villagers involved in agriculture also resent the lack of access to markets for their goods. Merchants that travel to the Delta in order to buy cattle offer prices that are considered unfair and the owner often prefer to keep the animals, even in a state of semi-wilderness, instead of selling them.

5 Ecotourism – sustainable tourism

The new Danube Delta's situation, a protected area, determined a tourism reorganization process that develops on this territory in the context of the sustainable capitalization of the natural resources and especially of the landscape resource.

5. 1 The legal frame of tourism practicability in the DDBR

The touristic activity develops in the Danube Delta according with the enforced laws and regulations, regarding the touristic service furnishing, and the Transport, Constructions and Tourism Ministry.
Once with the declaring of Danube Delta as a Biosphere Reserve, the DDBR Authority instituted **its own measure and rules** for tourism practicing on DDBR's territory. So, **9 touristic areas** and **26 touristic routes** have been selected where it is permitted the developing of the organized or individual tourism activities.

The tourism companies that operate on the DDBR's territory have the obligation to use only the established touristic routes where they develop – only with a license – their touristic activities. The touristic access in the areas outside the touristic routes is allowed only by rowing boats.
Once with the tourism development in the DDBR, a part of these regulations needed modifications, actualizations or the constraint of new restrictive rules. The presence in a bigger and bigger number of fast motor boats imposed the elaboration of a new naval circulation regulation, focused especially on the powerful boats speed reduction on channels and lakes.

For the touristic activity development on the DDBR's territory, the tour-operators must respect "**The rules of tourism development in the DDBR**" too, rules imposed by the DDBR Authority. These rules compel the touristic service suppliers and tourists to respect the measures taken by the DDBRA for the deltaic ecosystem protection and for the reduction of the touristic activity negative impact over the deltaic ecosystem.

The development of the touristic activity on the DDBR's territory is conditioned by the obtaining of the touristic activity development and/or practicing authorization from the DDBRA's Regulation-Authorization-Development Service and of the DDBR's access tax payment.

Several touristic activities, such angling and hunting, needed special regulation occur in DDBR complex. For the practicing of these activities, certain DDBR's areas were authorized, selected on the criteria of accessibility, low impact over the wild fauna and the non-belonging to strictly protected areas. These touristic/entertaining activities can so develop only in special delimited areas, approved by the DDBRA and under the co-ordination of the local Associations for Angling and Hunting. Tour-operators that offer touristic programs for angling and hunting in the DDBR and the individual tourists must comply with the existing legislation regarding the fishing prohibition periods and the one regarding the allowed hunting species.

5.2 The touristic potential

The natural and cultural values of the Danube Delta represent the natural and human touristic resources of the DDBR, recoverable resources through the tourism practicing. These values represent in the same time touristic attractions that create the DDBR touristic product and they can be grouped as follows:

Natural touristic resources

- The landscape
- The delta's biodiversity
- The natural resources
- The DDBR's climate

Human touristic resources

- The Danube Delta's culture and history
- The human settlements

These delta's natural values that creates and represent the DDBR's touristic potential, permit the practicing of a diverse range of tourism aspects:

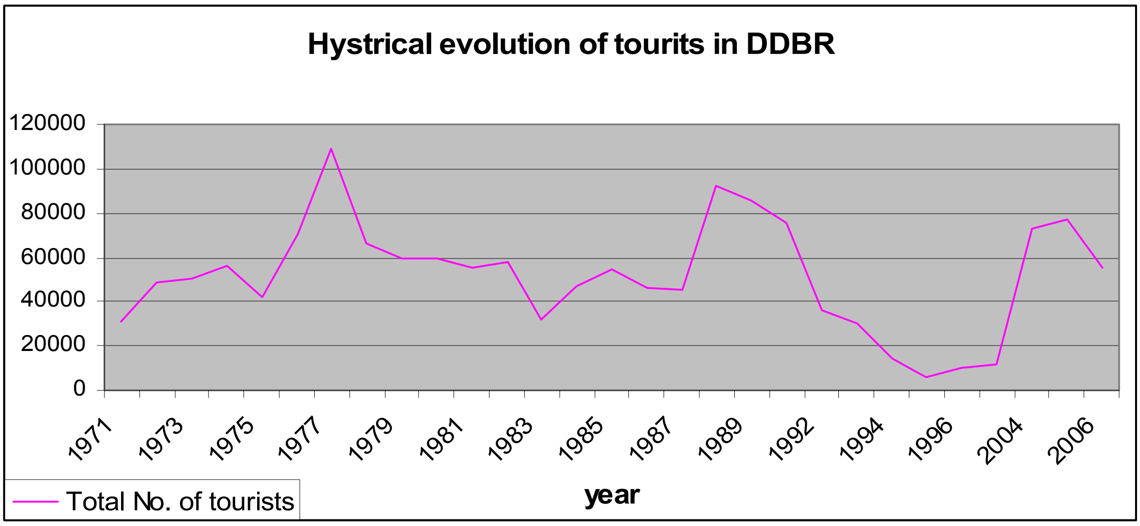
- **resting holiday**, practiced through the big tourism companies, in one of the hotels within DDBR's territory or on the floating hotels;
- **itinerary tourism**, practiced both individually and through organized excursions, with a variable period;
- for **nautical sports** practicing;
- for **angling and hunting**;
- **specialized tourism,** for ornithologists, botanists, ichthyologists, etc.;
- **special programs for young people** for the nature knowledge, understanding and appreciation;
- **rural tourism** in which the tourists are lodged (accommodation and meal) and guided by the local people;
- **sun-marine cure** on the beaches of Sulina, Sfantu Gheorghe and Portita;
- **photo-safari** practiced by the people that want to catch on picture the Danube Delta's landscape.

5.3 History evolution of tourists within the Danube Delta

Around 98-99% of tourists in the county actually visit the Danube Delta (Apolon 2003). Still, tourism has started to re-develop in recent years, along new lines (Figure 33). The year 2004 was the most prolific year after 1990, increasing with almost 50 % towards 2003, due to the supportive publicity in mass-media and the investments in new accommodations structures and new more attractive and diversified tourism services packages. In the year of 2004, the number of tourists recorded was of 77 306 persons.

The year of 2005 began under the good premises, especially in terms of the development of the tourist infrastructure, because the tour operators were sensing an ascendant tourist trend towards DDBR. Unfortunately, the spring floods compromised the tourist season, and the autumn's flue bird caused the canceling of their visit by the foreign tourist groups.

Figure 33 Historical evolution of tourists



Although the tourists' number received in the accommodation structures on the Tulcea's territory knows an increase in 2004, the potential of these structures is not valued at their full capacity. The using level of the accommodation structures from a certain tourism area represents tourism indices largely used in the tourism industry.

There is a consensus among local people and policy-makers at various levels that tourism and in particular rural-tourism has the potential to provide a significant alternative to fishing and agriculture in the DDBR, and to become a source of welfare for the region. Recent years have witnessed a gradual development of rural-tourism facilities, with increasing numbers of households investing in their accommodation capacity, but also an increase in tourist facilities operated by private businesses.

Now, the accommodation offer in the DDBR is about 4 500 places (Table 11) in hotels, floating hotels, urban and rural board and lodgings, little houses, bungalows, touristic halts or camping. Comparing with 2003, there is a powerful development of the touristic lodging structures, both qualitative and quantitative.

Table 11 Tourists accommodation capacity in 2004 comparing with 2003

No.	Lodging structure type	Capacity Places (2003)	Capacity Places (2004)
1	Hotels	1018	1252
2	Floating hotels	252	522
3	Camps	320	244
4	Huts	26	20
5	Board and lodging	459	856
6	Touristic halts		50
7	Touristic villages	262	488
8	Holiday camp	770	770
9	Villas		248
10	TOTAL	3107	4450

The recreational activity's offer contains: trips in the delta by motor boats, catamarans or rowing boats, bird watching, angling, delta's exploring with kayaks, the localities visiting, traditional meals, etc.

The prices (per day/person) for the offered services find in the following categories:

- 15 Euros (min.) – local households
- 25 Euros – board and lodgings
- 50 Euros – floating hotel **
- 100 Euros – comfort ***
- 150 Euros – comfort ****
- 210 Euros – comfort ***** (Delta Nature Resort - Somova)

6. Ecological restoration in the framework of Danube Delta Biosphere Reserve management

One of the main objectives of the management of Danube Delta Biosphere Reserve, as formulated in 1994 with IUCN and UNESCO assistance was to "maintain or restore the natural operation and functions of the delta ecosystem", coming up as general objective 8 in "Management Objectives for Biodiversity Conservation and Sustainable Development in DDBR, Romania"(1995) as follows: "carry out ecological restoration work where the natural or seminatural character of the area has been lost as a result of human activity" by two projects:

1. Formulate the criteria for identifying sites and implementing restoration projects based on international practice in restoration ecology
2. Devise and implement a strategy for ecological restoration of and/or habitat creation in abandoned polders, taking into account any present ecological value they may have

The restoration programme elaborated for the Danube Delta started in 1992 with the criteria for scientific basis of ecological restoration actions in the Danube Delta Biosphere Reserve GOMOIU and BABOIANU(1992) :

- approaching the "philosophy" of deltaic nature, to the initial structure for the ecosystems(wetland prevailing, West-East waterflow etc.);
- identification of ecological optimum for every ecological restoration case (hydrological optimum, chemical optimum, economical optimum etc.);
- analyses of every proposed zone for ecological restoration in comparison with the rest of the delta and to balance individual-holistic proportion regarding both structures and functions of ecosystems;
- taking into account in all ecological restoration of aquatic systems the important role of the Danube River water quality, resulting the necessity of water quality improvement in whole Danube River basin .

Establishing the priorities on restoration works, finding the function valences of proposed places for ecological restoration, establishing the ecological factors stability degree, the parameters which must be controlled and risk restoration factors, represent some methodological demands for successful restoration works GOMOIU and BABOIANU(1992).

In 1993 a pilot project focusing the rehabilitation of the agricultural polders Babina (2 200 ha) and Cernovca (1 580 ha) was initiated. This was intended to be the first of a range of further common rehabilitation projects.

To respond to the complex requirements of the rehabilitation works it was necessary:

· to investigate the structure and condition of the terrestrial and aquatic ecosystems,

· to determine the degree of structural alterations of biocoenoses and ecosystems compared to the former situation,

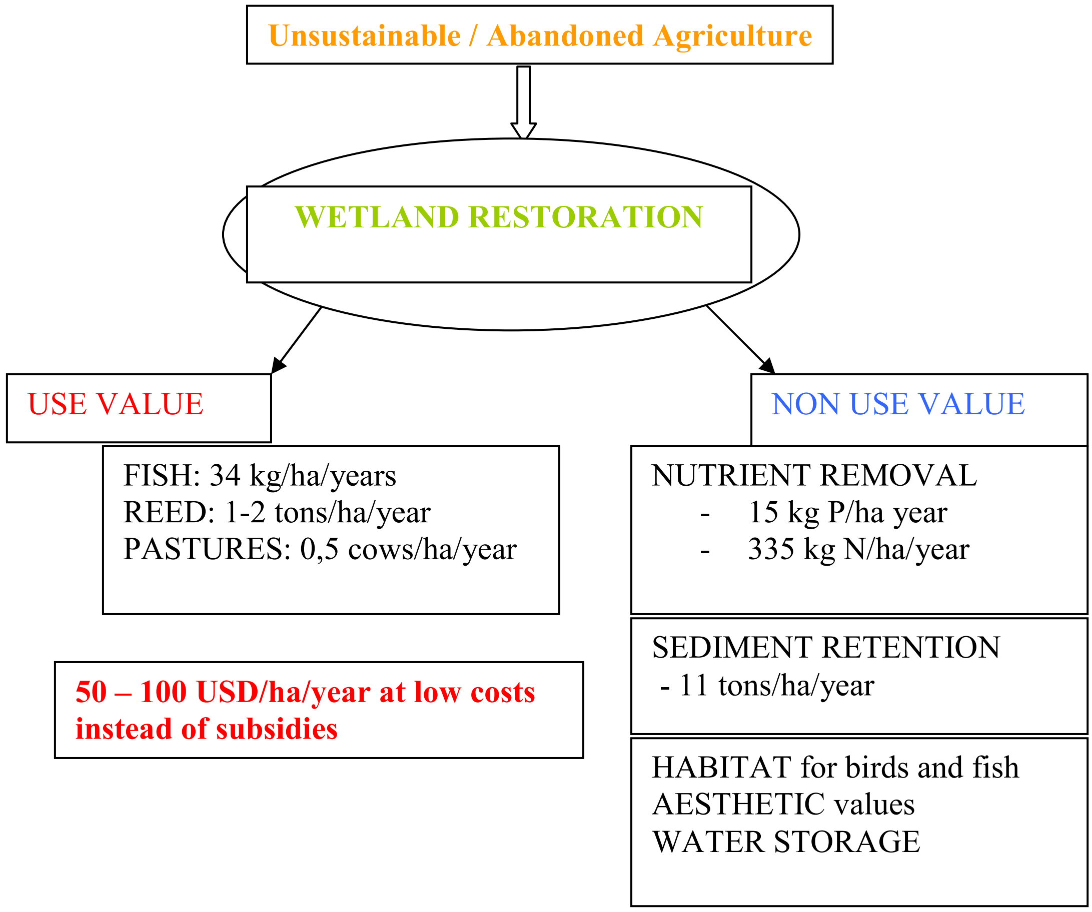
· to proceed to an analysis of the ecological situation on the basis of indicator species in order to elaborate forecasts regarding the probable development of the ecosystem,

· to elaborate and guarantee ecological monitoring as a means of a success controlling for the measures performed.

The proposed solution for a near-natural reestablishment of uncontrolled flooding was to create small openings in the surrounding dike. Four openings allowing a water inflow at levels superior to + 1.00 m over Black Sea level (Sulina) have been planned for

Babina and two openings for Cernovca. The goal was to allow uncontrolled flooding while using the existing channel network for the filling and emptying of the polder.

Benefits of the restoration agricultural polder area (Babina case study)



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5.5. Doñana case study

Preamble: Doñana seen from Europe or the LEAC story

Land cover accounts can give a first useful picture of Doñana and its recent evolution. This picture presents the park in its (land cover) environment and offers gateways to the broad European picture as well as to other sites with which comparisons are fruitful. These accounts being based on a grid (on the following maps, a 1 km2 grid is used) they are an efficient framework for integrating socio-economic statistics and ecological monitoring data.

First, the Corine map:

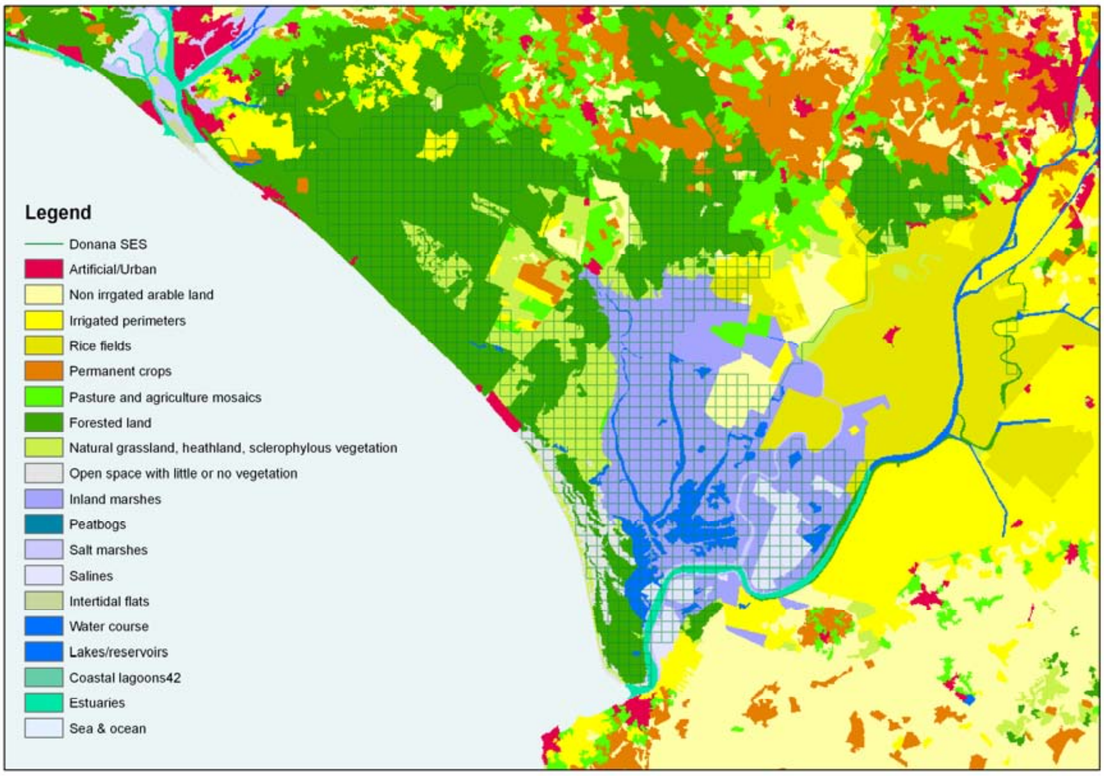


Figure 5.5.1 Doñana land cover; CLC2000

The same tables as produced for the whole Mediterranean basin can be established for the site. They tell about:

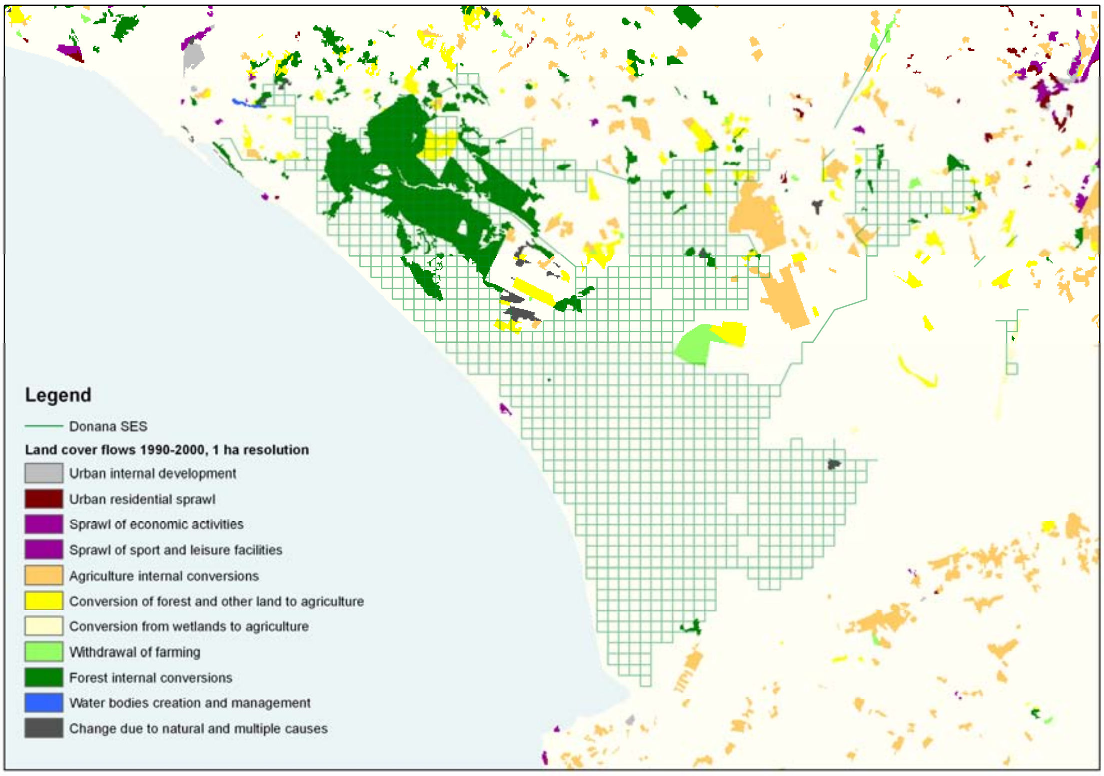
Land cover:

		Donana		
		1990	2000	Net change
111	Continuous urban fabric	110	118	8
112	Discontinuous urban fabric	28	28	0
121	Industrial or commercial units	25	38	13
122	Road and rail networks and associated land			0
123	Port areas			0
124	Airports			0
131	Mineral extraction sites	253	263	10
132	Dump sites	30		-30
133	Construction sites	43	67	24
141	Green urban areas			0
142	Sport and leisure facilities	18	61	43
211	Non-irrigated arable land	5803	5302	-501
212	Permanently irrigated land	3139	4302	1163
213	Rice fields	2792	3144	352
221	Vineyards	30	30	0
222	Fruit trees and berry plantations	479	868	389
223	Olive groves	831	806	-25
231	Pastures			0
241	Annual crops associated with permanent crops	21		-21
242	Complex cultivation patterns	589	883	294
243	Agriculture mosaics with natural vegetation	1020	1138	118
244	Agro-forestry areas	325	324	-1
311	Broad-leaved forest	18969	7695	-11274
312	Coniferous forest	29661	29610	-51
313	Mixed forest	1556	1370	-186
321	Natural grassland	3243	3174	-69
322	Moors and heathland			0
323	Sclerophyllous vegetation	12601	11127	-1474
324	Transitional woodland shrub	13571	25646	12075
331	Beaches, dunes and sand plains	4324	3629	-695
332	Bare rock			0
333	Sparsely vegetated areas			0
334	Burnt areas	93		-93
335	Glaciers and perpetual snow			0
411	Inland marshes	31471	31666	195
412	Peatbogs			0
421	Salt marshes	1088	1088	0
422	Salines	4811	4872	61
423	Intertidal flats			0
511	Water courses	742	510	-232
512	Water bodies (lakes & reservoirs)	7500	7416	-84
521	Coastal lagoons			0
522	Estuaries	1793	1793	0
523	Sea and ocean	9		-9
	TOTAL	**146968**	**146968**	**0**

Land cover flows 1990-2000

		Donana
		Flows 1990-2000
lcf12	*Recycling of developed urban land*	15
lcf21	*Urban dense residential sprawl*	8
lcf22	*Urban diffuse residential sprawl*	
lcf31	*Sprawl of industrial & commercial sites*	6
lcf35	*Sprawl of mines and quarrying areas*	10
lcf37	*Construction*	23
lcf38	*Sprawl of sport and leisure facilities*	43
lcf412	*Diffuse extension of set aside fallow land and pasture*	331
lcf421	*Conversion from arable land to permanent irrigation perimeters*	327
lcf422	*Other internal conversions of arable land*	248
lcf433	*Other conversions between vineyards and orchards*	12
lcf441	*Conversion from permanent crops to permanent irrigation perimeters*	18
lcf442	*Conversion from vineyards and orchards to non-irrigated arable land*	
lcf444	*Diffuse conversion from permanent crops to arable land*	
lcf451	*Conversion from arable land to vineyards and orchards*	186
lcf463	*Diffuse conversion from pasture to arable and permanent crops*	35
lcf511	*Intensive conversion from forest to agriculture*	435
lcf512	*Diffuse conversion from forest to agriculture*	73
lcf521	*Intensive conversion from semi-natural land to agriculture*	1079
lcf522	*Diffuse conversion from semi-natural land to agriculture*	300
lcf53	*Conversion from wetlands to agriculture*	223
lcf54	*Other conversions to agriculture*	22
lcf62	*Withdrawal of farming without significant woodland creation*	308
lcf71	*Conversion from transitional woodland to forest*	1170
lcf72	*New forest and woodland creation, afforestation*	1323
lcf73	*Forests internal conversions*	121
lcf74	*Recent fellings, re-plantation and other transition*	12526
lcf81	*Water bodies creation*	8
lcf91	*Semi-natural creation and rotation*	323
lcf93	*Coastal erosion*	
lcf99	*Other changes and unknown*	70
	No Change	127725
	TOTAL	**146968**

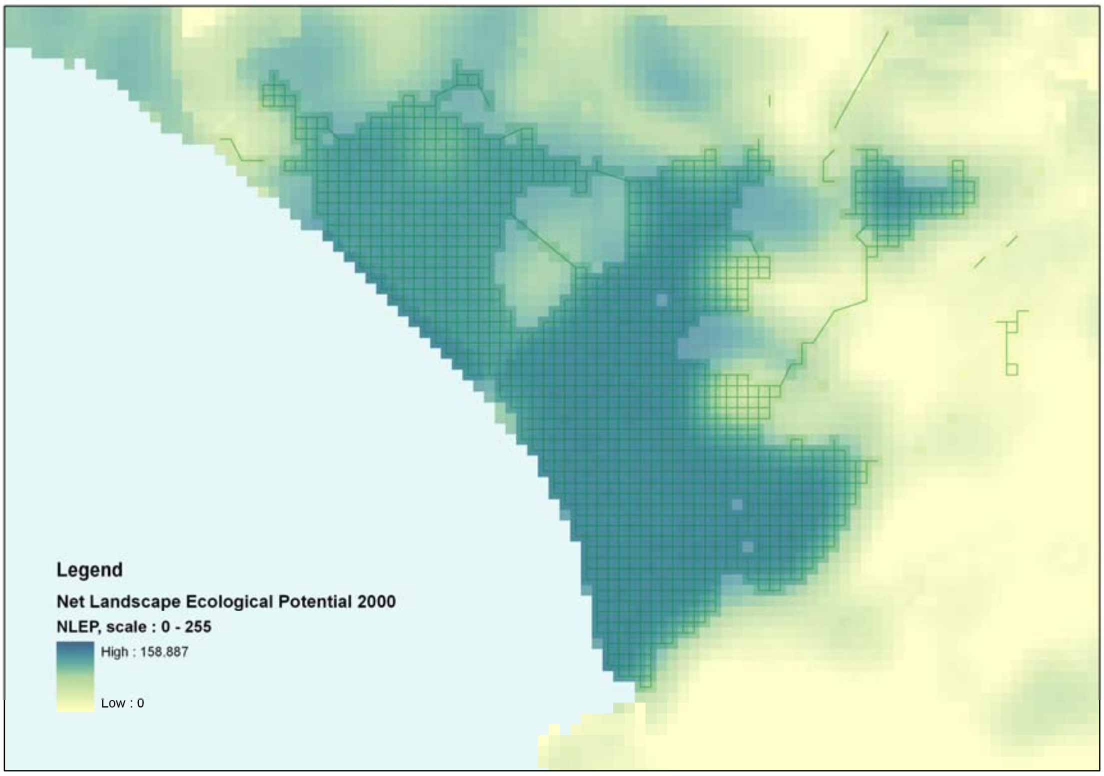
These flows can be mapped as well:

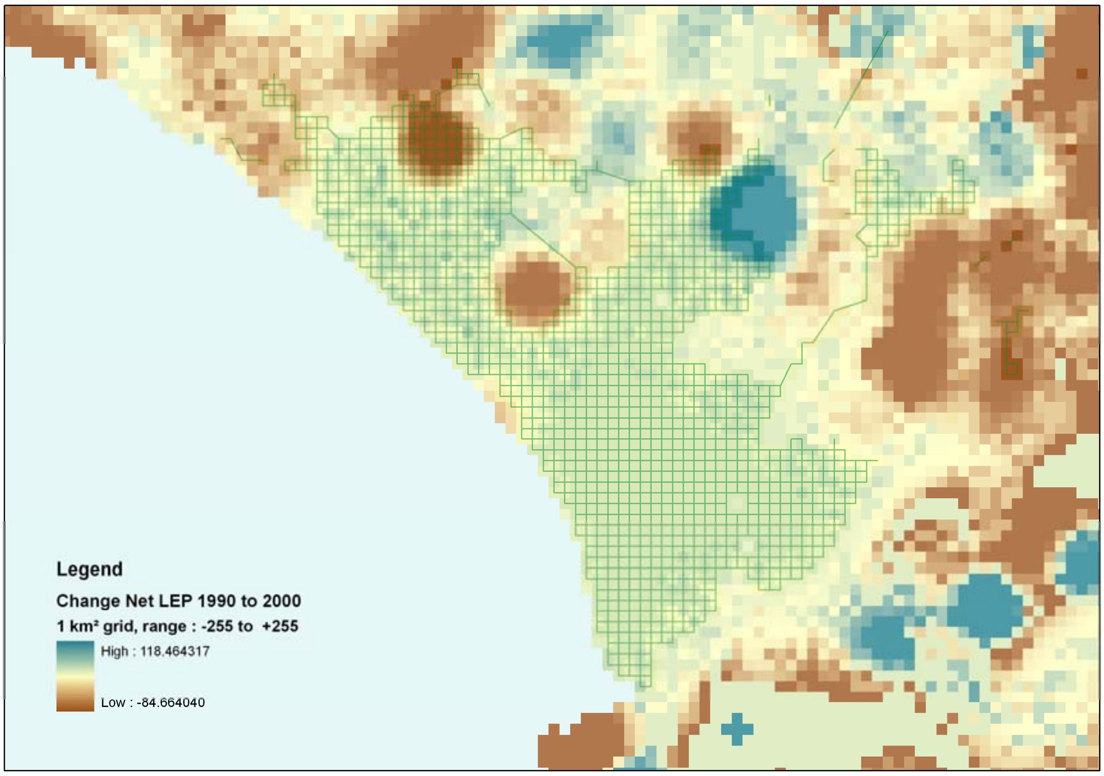


And first land and ecosystem physical aggregates:

		Units	DONANA SPAIN
Surface of coastal SES Wetlands		km²	1473
TOTAL VALUES IN SES	Urban temperature 2000	0-100	739
	Change in Urban temperature 1990-2000	0-100	74
	Intensive Agriculture Temperature 2000	0-100	19690
	Change in Intensive Agriculture temperature 1990-2000	0-100	995
	Landscape Net Ecological Potential 2000	0-100	180982
	Change in Landscape Net Ecological Potential 1990-2000	0-100	-4098
	Nature designation index (combined N2000 & national)	0-100	117894
	Effective Mesh Size 2005	logN(MEFF)	278560
	Population 2000	inhabitants	11023
MEAN VALUES PER KM² IN SES	Urban temperature 2000	0-100	0.50
	Change in Urban temperature 1990-2000	0-100	0.05
	Intensive Agriculture Temperature 2000	0-100	13.37
	Change in Intensive Agriculture temperature 1990-2000	0-100	0.68
	Landscape Net Ecological Potential 2000	0-100	122.87
	Change in Landscape Net Ecological Potential 1990-2000	0-100	-2.78
	Nature designation index (combined N2000 & national)	0-100	80.04
	Mean Effective Mesh Size in SES 2005	logN(MEFF)	189.11
	Population Density (inhab/km²) 2000	inhabitants	7

…which can be mapped using the same 1km² grid


Legend
Net Landscape Ecological Potential 2000
NLEP, scale : 0 - 255
High : 158.887
Low : 0


Legend
Change Net LEP 1990 to 2000
1 km² grid, range : -255 to +255
High : 118.464317
Low : -84.664040

Introduction: Description and history of the area

The Doñana coupled social-ecological system (SES) (South-West Spain) covers an area of 3.120 km^2, more than one third of which is protected. Doñana encompass two important protected, the Doñana National Park and the Doñana Natural Park, unified in 2005 in the Doñana Natural Area. It embeds other smaller protected sites and is also protected through international agreements (Ramsar Site, Reserve of the Biosphere).

Doñana consists of a wide system of marshes, dunes and beaches, associated with the coastal dynamic of the Guadalquivir River's mouth, sometimes referred to as the Doñana fluvio-littoral system (Fig. 1) (Montes et al., 1998). It embeds four main types of ecosystems at the ecodistrict scale: the coastal system, the aeolian sheets of sand dunes and two wetland ecosystems: the **Guadalquivir River Estuary** (36 km^2; 77 km long; tidal influence: 110 km from the river mouth) and the **Doñana marsh** (original surface: 1.663 km^2), which is the flood plain of the Guadalquivir river.

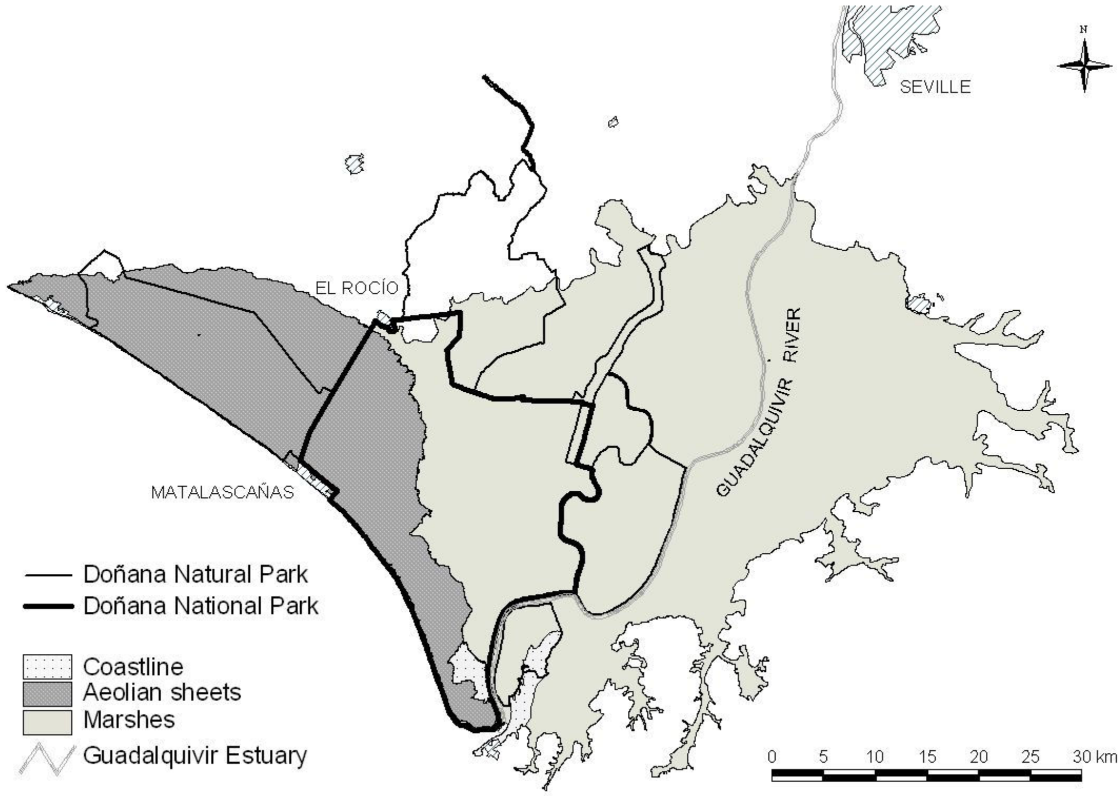


Figure 1. The Doñana fluvio-littoral Ecosystem of Doñana: ecodistrict and main protected areas.

Because of its historical context of isolation and its privileged location (interface between the Atlantic and the Mediterranean, between Europe and Africa), Doñana constitutes a unique wetland ecosystem performing diverse ecological functions: major stopover point in the migration route of birds moving between Europe and Africa, habitat provision for emblematic, endemic, threatened and flag species, such as the Iberian lynx and the imperial eagle, etc. Doñana is currently considered to be one the most significant wetlands in Western Europe (Fernández Delgado, 2005).

The Doñana SES embeds 12 municipalities of three different provinces of the Andalusia region, summing 174.000 inhabitants (Lomas et *al.*, 2007). Well-being and local economy in all these municipalities largely depend on the ecosystem services provided by the Doñana fluvio-littoral ecosystem. Main traditional economic activities in this region have been extensive cattle farming, forestry and agriculture (grapevine, orchards and cereal), together with diverse subsistence uses such as hunting, fishing and picking up goods. Currently, agriculture and tourism are the main sources of income related to Doñana's ecosystem services.

Doñana has historically been subject to a wide range of traditional economic uses coupled to local ecosystem's dynamics (Rodríguez Merino & Cobo García, 2002). This allowed its inhabitants to obtain diversified flows of ecosystem services at the same time ecological functions were preserved. Multiple land uses in adaptive mosaics has been the dominant landscape management model in Doñana until a few decades ago. While many wetlands were largely desiccated in western European countries during the 18th and 19th centuries in order to control malaria and increase land productivity, large-scale territorial transformation arrived late to Doñana. Although decision makers conceived Doñana to be a marginal land that had to be drained and converted into a more economically productive area, all trials of reclamation in the 19th century failed due to lack of technology, access roads and investments (González Arteaga, 1993).

For a summary of Doñana SES, see table 1.

Table 1. General view of the Doñana SES

Characteristics	**Description**
Location	Andalucía Region, South-West Spain
Spatial extent	3.120 km^2
Biophysical system of reference	Doñana fluvio-littoral ecosystem (212.000 ha)
Municipalities	12 mun.: Lucena, Moguer, Almonte, Hinojos, Pilas, Villamanrique, Azanalcázar, Puebla del Río, Isla mayor, Lebrija, Trebujena
Human population	174.172 inhabitants; Density: 56 inhabitants / km^2
Natural protected areas	Doñana Natural Area (National Parc + Natural Parc), Ramsar Site, Biosphere Reserve
Wetland ecosystems	Guadalquivir River estuary (3.600 ha, 77 km long, tidal influence of 110 m from the river mouth) and marsh (166.300 ha)
Main ecosystem services	Agriculture, cattle farming, tourism, research, clean water, flood prevention, sedimentary balance, refugee for biodiversity
Other ecosystem services	Fishing, seafood, environmental education, nutrient cycling
Characterization of economic system	Agriculture ()
Characterization of political and administrative institutions	Local: Doñana protected area, Patronato, municipalities. Reg./Nat.: Andalucía Government; Ministry of the Environment International: European Union, United nations
Characterization of culture	Religion: Christian Catholics; main cultural events: *El Rocío* pilgrimage, *Saca de yeguas*
Environmental problems and disturbances	Floods, diseases outbreaks, droughts, oscillations of agricultural subsidies and market prices
Methodology used in this work	Maps, bibliography revision, statistical data, interviews

Transformations and drivers of change in Doñana in the 20th century

At the first decades of the 20th century, Doñana was an almost unique case of wetland conservation in the European context. It remained as a feeble populated and almost isolated area, without any important access road. Ecosystem services were obtained through a small scale subsistence economy based on multiple land uses. This situation started to change by 1929, with different management policies that aimed to increase the added value (in market terms) of ecosystem services. This aim was accomplished through land reclamation and the development of intensive agriculture, the settlement of forest plantations (eucalyptus and pine-trees) for wood and pulp production, and beach tourism. These policies resulted in both economic development and ecological degradation, affecting ecosystem functioning all four main ecosystems of Doñana (Montes, 2000). Market integration and the intervention of the State are among the most powerful drivers o change in Doñana during the 20th century (Ojeda Rivera and Moral Ituarte, 2004; Gómez Baggethun and Kelemens, In press).

Development and growth

Until 1927, the Doñana marsh fully maintained ecological health and integrity, remaining as a non converted ecosystem. The marshes were resilient to secular human interventions and small scale disturbance (cattle farming and slash and burn), and ecological functions were preserved. Between 1929 and 1956, private companies drained large areas of the marshes in order to cultivate rice. The transformation process continued through reclamation performed by the State during the 1956-1978 period, when the upper and part of the lower marsh was drained for further agricultural purposes. In the same period, the State implemented an extensive forest plan to replant the aeolian mantles with eucalyptus, destroying more than half of the cork tree forest (Montes, 2000). The Plan Almone-Marismas, a major project to irrigate crop with groundwater was planned in the 60's and implemented in the 70's leading to the settlement of 8.000 ha of permanently irrigated lands. Hydrological regulation functions such as aquifer recharge were affected due to both high evapotranspiration rates of eucalyptus plantations and over-extraction from the aquifer for irrigation purposes (Custodio, 1995).

In the coastal system, urban development projects in the coast were deployed since 1969 in the context of a national strategy to increase revenues from beach tourism. The beaches of the area were declared of national interest for tourism, resulting in the major urbanization of Matalascañas. Further urbanisation plans of the beach during the 90's finally failed after the 1st Sust. Dev. Plan of Doñana was approved in 1993.

Although the transformation of the estuary of Doñana started in the 19th century, this process was accelerated in the 20th century as the Guadalquivir River branches were progressively channelled in order to shorten the navigation distance to Sevilla (Menanteau, 1984). The second half of the 20th century thus coincides with a deep transformation process involving the simplification of ecosystems by management strategies that aimed to increase productivity by the enhancement of intensive mono-functional land uses (rice, eucalyptus plantations, urbanisation for tourism, etc).

Conservationist policies

In the 1960's, as a response to this fast transformation process, European institutions and conservationist organizations promoted policies to preserve remaining sites with high value for biodiversity conservation. Since the declaration of the National Park in 1969, protected areas in Doñana have been extended up to now through the declaration of new protection categories and through the enlargement of the existing protected areas (Table 2). As natural capital and non converted areas have become scarcer in European countries, the social perception of Doñana has dramatically changed during the last few decades.

Table 2. Declaration of protected areas in Doñana since 1964

Year	Event / Conservation figure	Protected area (ha)	Increase in total prot. area (ha)	Total protected area (ha)
1964	Doñana Biological Reserve	6.784	6.784	6.784
1969	Doñana National Park (DNP)	34.625	27.841	34.625
1779	Enlargement of DNP	50.720	16.095	50.720
1980	Doñana Reserve of Biosphere	77.260	26.540	77.260
1982	Ramsar Site	50.720	0	77.260
1988	ZEPA	50.720	0	77.260
1989	Buffer zone for DNP (Doñana Natural Park)	53.709	27.169	105.765
	Brazo del este river branche (Paraje Natural)	1.336	1336	
1991	*Reserva Natural Concertada de la Cañada de los Pájaros*	5	5	105.770
1997	Doñana Natural Parc	53.835	126	105.896
2000	*Reserva Natural Concertada de La Dehesa de Abajo*	617	617	106.513
2001	*Monumento Natural Acantilado del Asperillo*	11,85	0	106.513
	Declaración del Monumento Natural Acebuches del Rocío	0,64	0	
2002	ZEPA enlargement	104.555	0	106.513
2004	Enlagement of DNP (also adjustments in the Doñana natural park	54.250	3.858	**110.043**

Conservationist policies entailed the prohibition of most socio-economic activities within the protected areas except those related to ecotourism and a few traditional uses, affecting provisioning services and the stakeholders whose livelihoods depended on them. As a consequence, during the last few decades Doñana has been subject to increasing subsidies in order to attenuate social conflicts emerging in relation to conservationist restrictions. Following Ojeda Rivera (1993), the permanent flow of subsidies, often unrelated to the existing local socio-economic tissue, has derived in the establishment of a subsidized culture in Doñana that discourages initiatives for endogenous development.

The implementation of strict conservation strategies in Doñana had thus different effects. On one hand, they have managed to slow down the ecological degradation process, for instance achieving to stop the urbanization of the coast, the further reclamation of remaining natural marshes, and the development of linear infrastructures with high impact on habitat fragmentation. On the other hand, it has affected some traditional uses as well and thus the local ecological knowledge related to them.

5.1.2. Basic accounts

5.1.2.1. Land-use cover change accounts

The main changes on the land-use cover are summarized in table 3.

Table 3. Changes in land-cover in the 1956-2006 period. Source: Modified from Zorrilla, 2006.

Land cover (has)	1956	1977	1988	2006
Artificial				
Water infrastructure	0	0	164	291
Urban	138	501	928	928
Agricultural areas				
Aquiculture	0	0	3608	3482
Rice fields	5040	27740	40751	40751
Irrigation lands		23407	45193	45182
Non-irrigated land	6922	14770	18581	14913
Greenhouse agriculture	0	0	162	154
Drained marsh	54743	41894	15033	10189
Salines	156	930	1304	1304
Natural areas				
Marsh water flows	5734			
"Lucios" (shallow, seasonal lakes)	6417	546	565	565
Restored marshes	0	0		7952
Non-transformed marshes	77508	46300	30205	30783
Fluvial beaches	1371	4711	3288	2885
Water courses and estuarine	5740	4315	4303	4706
Other	1810	431	1494	1494
TOTAL	**165579**	**165579**	**165579**	**165579**

5.1.2.2. Water: hydroperiod of Doñana wetland

Overall, changes in the original marsh (estimated 1663 km^2, see Fig. 2.) at the beginning of 20th century have led to the current 270 km^2 of shallow water (lost of 82%). In addition to wetland area reduction, tidal influence, one of the main inundation drivers, was also limited by the construction of a wall along the Guadalquivir River (Fig. 3). As a consequence, the marsh became isolated from the estuary, loosing both the influence of tidal flow and of river discharges (García Novo, 1997).

These drivers have produced over last century strong changes on the hydroperiod of Doñana marshes. Díaz-Delgado et al. (2006) found that there are two types of areas in Doñana wetland related with the hydroperiod changes (Fig. 4):

a. those areas where the hydoperiod decrease because (1) they are isolated from the original water inflows –number 1 in Fig. 4 -, or (2) they are altering topography due to accelerated siltation processes –number 3 in Fig. 4-,.
b. those areas where the hydroperiod increase because of (1) siltation processes are acting as casual damps, promoting inundation in upstream areas –number 2 in Fig. 4-,, and (2) because of the appearance of new areas liable to flooding, such as fish cultures – number 4 in Fig. 4-,.

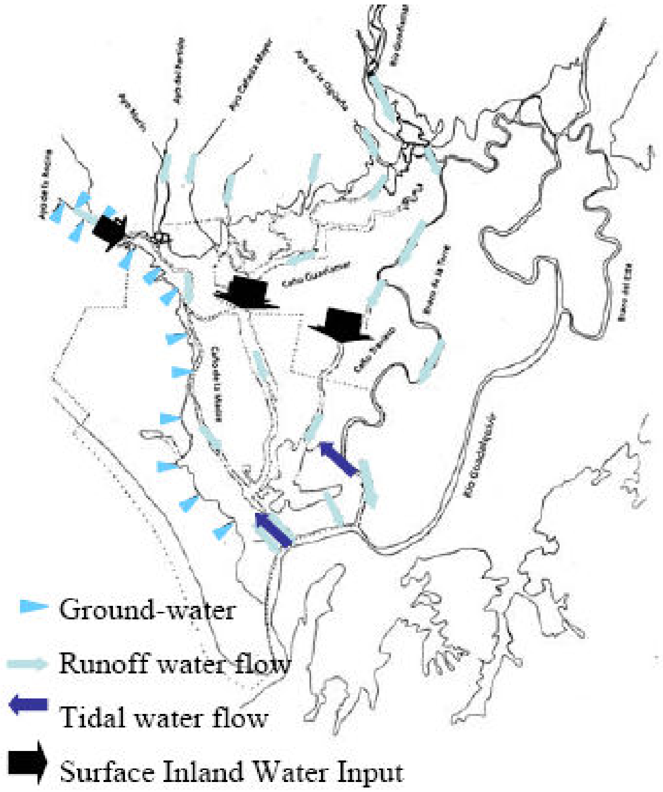


Figure 2. Water inflows at the early XX century in Doñana (Díaz-Delgado et al., 2006)

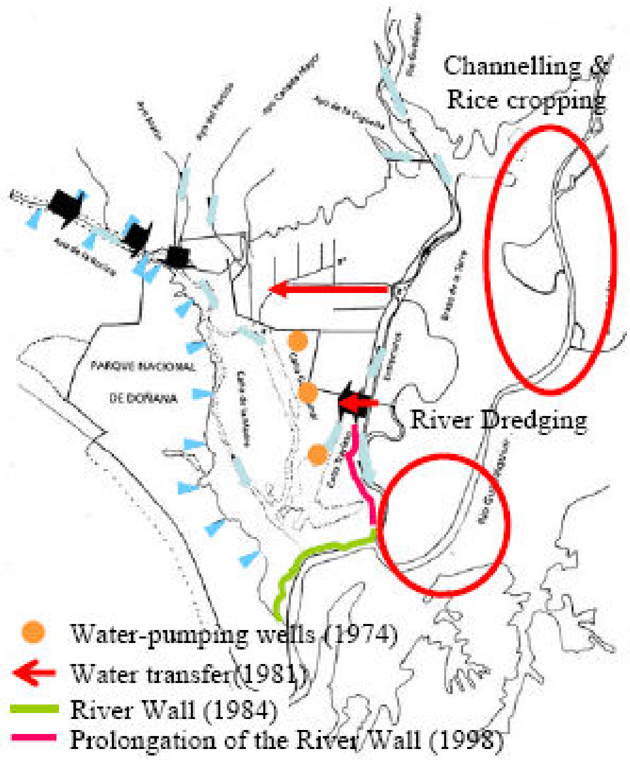


Figure 3. Doñana marshes after 1998 (Díaz-Delgado et al., 2006)

This study also found that the hydroperiod changes in Doñana can be explaining up to 70% by the accumulated annual rainfall (fig. 5), while the 30% of variance are related to human explanations.

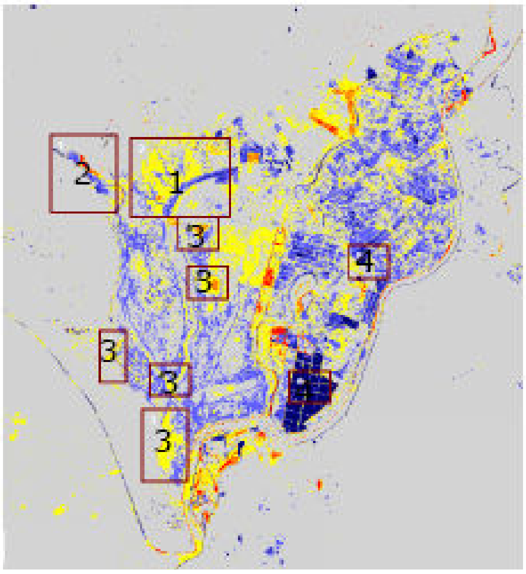


Figure 4. Areas with relevant changes on the hydroperiod (1985-1995 vs. 1995-2004) (Díaz-Delgado et al., 2006)

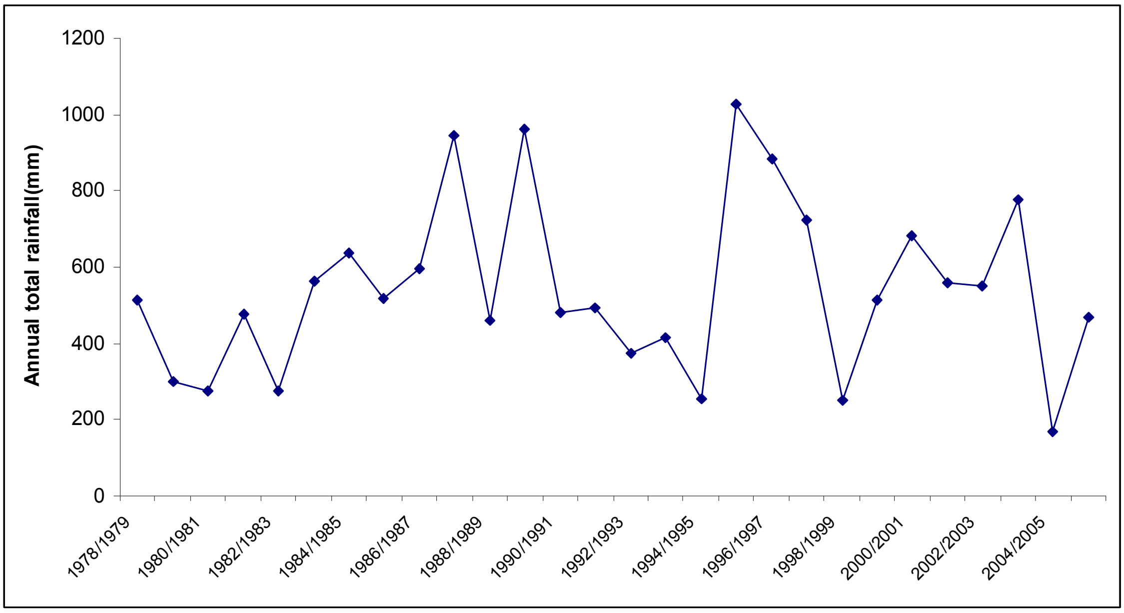


Figure 5. Total annual rainfall by hydrological cycle

5.1.2.3. Biodiversity: changes in the status of important species

Ecological keystone species

Ecological keystone species are those considered exceptional, relative to the rest of the community, in maintaining the organization of the ecosystems (Paine, 1969, Mills et al., 1993). In the Doñana social-ecological system, the European Rabbit (*Oryctolagus cuniculus*) is recognized as a keystone species because the conservation of most raptors depends on the stability of their populations due to their specific diet (Fig. 6, Delibes-Mateos et al., 2007).

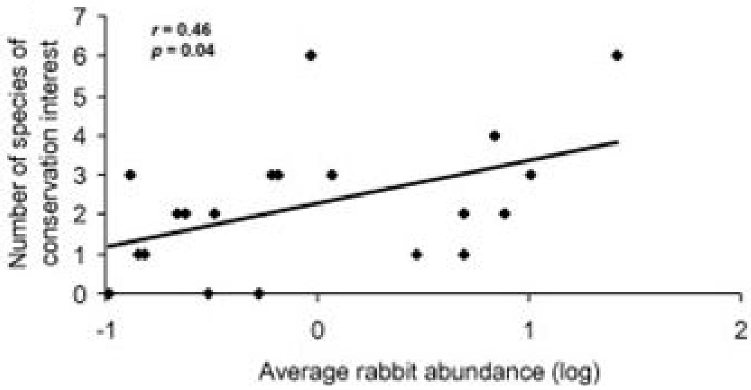


Figure 6. Relationships between the average rabbit abundance and the number of species of conservation concern. Source: Delibes-Mateos et al., 2007.

From the early tears of the 20th century to the late of 1950, the tales and testimonies of old game keepers of Doñana confirm the abundance of rabbits. In 1959, the rabbit populations have undergone because of the appearance of myxomatosis (Ratcliffe et al., 1952). Valverde (1960) calculated a mortality rate of over 90%. Later, in 1970s, Pat Rogers observed an important decline of rabbit populations, although in a less dramatic rate than the trend observed by Valverde (1960). In these years, the rabbit populations are mainly localized in the ecotonal areas between aeolian mantle and marsh ecodistricts, i.e. La Vera. During the 1990s, two opposing phenomena take place: on the one hand, a recovery of populations (although not necessarily in the same places or to the same levels reported previously) as a consequence
of their greater resistance to myxomatosis and, on the other, a dramatic mortality rate, from the early 90s, due to the appearance of a new viral infection: rabbit haemorrhaging disease (Soriguer and Angulo, 2006). During the last ten years, there has been an important change in conservation policy, and most of the 26% of conservation funds during the last three years are invested on this species. Due to the decline in rabbit populations in the last years was attributed particularly to the abandonment of traditional practices, like the prescribed fire regime and clearing the brush, the conservation interventions started in 1985 in the form of clearing scrubs. These clearing operations had a positive effect on rabbit populations since 1988. Also, between 1993 and 1996, 8000 rabbits were transferred (Soriguer and Angulo, 2005); however most of these actions have not the efficacy that it was expected. Currently, there has been a slow but continued increasing trend for rabbit populations in Doñana.

<u>Cultural keystone species</u>
As the same way that certain species of plants or animals appear to exhibit a particularly large influence on the ecosystem they inhabit, as we can see in the previous section, the same is true in social systems. Garibaldi and Turner (2004) named these species as "cultural keystone species", and define them as the culturally salient species that shape in a major way the cultural identity of a people, as reflected in the fundamental roles these species have in diet, materials, medicine, tourism, and aesthetic or spiritual practices.

Cultural keystone species at global scale: iconic species
Despite the important conservation plans focused on the Spanish Imperial Eagle (*Aquila adalberti*) and the Iberian lynx (*Lynx pardinus*) in Doñana natural protected area (see

Fig. 11), they are in danger of extinction (Ferrer and Negro, 2004). The critical conservation status of Iberian lynx and Imperial eagle has been attributed to human persecution and habitat loss (Nowell & Jackson 1996). Raptors and mammalian carnivores were persecuted in Spain, and rewards were offered by the government for their eradication from the 1950s until the early 1970s, when protective laws were passed for all raptors and some carnivores (including the lynx). Today a significant proportion of lynx and imperial eagle populations are within nature reserves, and they have benefited from multimillion dollar Life Projects co-financed by the European Union and the Spanish government. These projects aimed to boost population sizes, but they did not succeed. These two flagship species tend to occur in Mediterranean ecosystems, and both prey preferentially on the rabbit (*Oryctologus cuniculus*), which also received a great percentage of the conservation budget in Doñana (Fig.11).

The Spanish imperial eagle (*Aquila adalberti*) is the most endangered bird of prey in Europe and one of the rarest raptors in the world (Collar and Andrew, 1988), with a total population estimated at little more than 140 pairs (Ferrer, 2001). The eagle population of Doñana National Park remained stable during the period 1976–1992 (Fig. 7), with 15–16 pairs breeding at high density (occupying 20,000 ha of available habitat inside the Doñana National Park with a mean territory size of 1200 ha). After 1992, this population suffered a notable decline dropping to only seven pairs in 2002 (Ferrer et al., 2003). Starting from 1993, the population size decreased by about 6% per year (Fig. 7). In 2002, an urgent action plan for the recovery of the eagle population was started in Doñana.

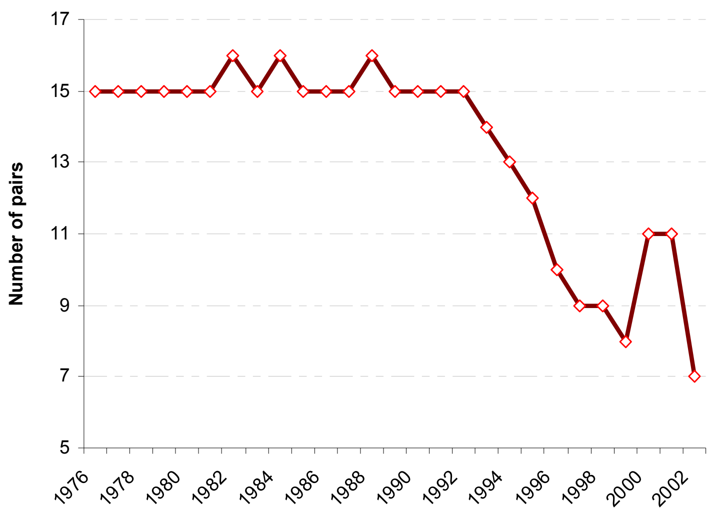


Figure 7. Decline of Spanish imperial eagle population in Doñana (Ferrer.et al., 2003)

The Iberian lynx is also a well-documented example of a carnivore suffering the consequences of human-induced mortality, scarcity of prey and habitat loss. Lynx habitat has been severely modified and reduced by extensive destruction (Delibes et al., 2000). By the early years of the 20th century, the Iberian lynx had become very rare in northern Spain, although it was still common in central and southern Spain (Pertoldi et al., 2006). By the 1960s, its range was essentially limited to the south-western quarter of the peninsula (Rodríguez & Delibes, 1992) (see Fig. 8).

The decline of the lynx population since the 1950s has been primarily caused by habitat loss and a decline of their main prey species, the European rabbit *Oryctolagus cuniculus*. In fact, there was a drastic population bottleneck during the 1950s and 1960s, when the myxomatosis viral disease hit the rabbit populations (Villafuerte et al., 1993). Recent estimates suggest that there are just two populations: the Doñana and the Sierra

Morena, inhabiting an area larger than 2000 km^2 and separated by more than 300 km (Pertoldi et al., 2006).

Figure 8. Three stages of the decline of the Iberian lynx populations in the second half of the 20th century: (a) estimated distribution in the 1960s (based on Rodríguez & Delibes, 1990); (b) estimated distribution in the 1990s (based on Rodríguez & Delibes, 1992); (c) breeding populations at present (based on Guzmán et al., 2003). TM, location of the extinct Montes de Toledo population; SM, Sierra Morena population; D, Doñana population. Source: Pertoldi et al. (2006)

The population of Doñana, with about 40–50 lynx, seems to have been isolated from the other surrounding and now extinct populations for more than 50 years, because of an expansion of croplands to the north and dense human settlements to the west (Rodriguez & Delibes, 1992). García-Novo and Marín-Cabrera (2006) also found other threats in Doñana that explain the collapse of its populations: draining of the marshes, the traffic on the roads between Almonte and Matalascañas and Mazagón and Matalascañas, clearing fields for crops, the large wells where they drowned, and the conflict with local people. Dead animals keep appearing, killed by hunters, run over by cars, poisoned or caught in traps. A broad sector of society is committed to defending the lynx, however another sector considers that it is responsible for its own extinction and they are opposed to traffic speed limits or to building crossings (García-Novo and Marin-Cabrera, 2006).

Another iconic species in Doñana are the aquatic birds. Important species of waterfowl to be found in the marshes and ponds include the marbled teal (*Marmaronetta angustirostris*), seen occasionally, the red crested pochard (*Netta rufina*) and the coot (*Fulica atra*). The crested coot (*F. cristata*) has become scarcer, while the gallinule (*Porphyrio porphyrio*) has become a very frequent sight in recent years. Some wandering specimens of the glossy ibis (*Plegadis falcinellus*), unseen since the 1960s, started to reappear in the 1990s and soon began to nest, beating the record in 2004 with a breeding population estimated to be at least 1,100 pairs over six colonies (García-Novo and Marín Cabrera, 2006).

5.1.3. Ecosystem Distress Syndrome Diagnostic

5.1.3.1. Loss of wetland ecosystems

The polderisation of the marsh started in 1928, and in 1998, 70% of it had been converted to mono-functional land uses for agriculture. During the period 1928-1934, the marsh of the left side down the river was drained and turned into crops. In 1958, the construction of a barrier isolated the marsh from several smaller water courses (Valverde, 2004). In 1966, the construction of another barrier almost isolated the marsh from the estuary's most important river branch (Brazo del Este), leading practically to the loss of its functioning (Barrera *et al.*, 1984).

Other disruptions of the hydrological dynamics include the channelling of the Guadiamar River and the Cigüeña water course which eventually lead to the isolation of 25.000 ha of the marsh between 1947 and 1977 (Ministerio de Asuntos Sociales, 1989). The mine spill of 6 hm3 of toxic mud in Aznalcóllar in 1998 affected 4.634 ha of the marshes. As a response to this ecological crisis, two important restoration projects took place starting a period of marsh restoration through two large projects: the Guadiamar Green Corridor and the Doñana 2005. Figure 9 presents the evolution of natural capital in marshes due to the previous transformations.

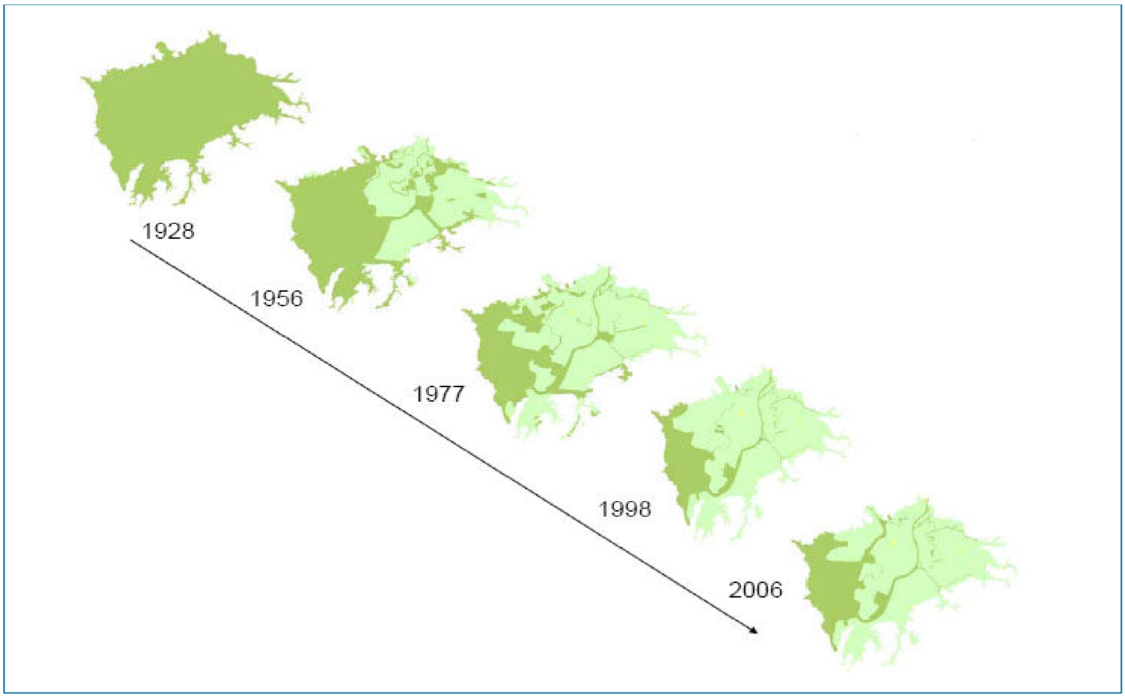


Figure 9. Natural capital loss in the Doñana marsh since 1928. Source: Lomas et al., 2007 (drafted after Zorrilla, 2006).

The channelling of the Guadalquivir rivers' estuary started in 1795 with the aim of facilitating navigation. It continued during the 19^{th} century and was accelerated since 1926. We can highlight different modifications of the estuary (Table 4), which all together have reduced its length from 125 to 77 km. (Menanteau, 1984). The river flow has speeded up increasing the sediment load and disrupting several hydrological regulation services such as the sedimentary balance or the erosion control.

Table 4. Transformation and rectification of the Guadalquivir estuary.

Year	Consequences
1795	Isolation of first branches (Río Viejo).
1816	Corta el meandro de El Borrego, que circunda Isla Cristina (en el Brazo de la Torre) y desvía el flujo fluvial al brazo central, aislando el Brazo de la Torre, que ya sólo recibiría aportes del Guadiamar.
1888	Construction of the *Casa Riera* channel between the Guadiamar and the Guadalquivir rivers.
1926	Isolation of *Los Remedios* and *La Tablada* areas
1951	The river do not pass anymore through Seville, which become isolated from the floods
1971-1972	Construction of the Sevilla-Bonanza navigation channel

5.1.3.2. Sedimentation /erosion

The **sediment load** to the marshes has increased dramatically due to loss of vegetation cover and land cover change towards agriculture. Sedimentation rates has raised from filling rates of less that 1 mm/ y during the last 2.500 years, to 3-6 mm/y during the last 50 years (Rodríguez Ramirez et al. 2005). The water storage capacity of the marshes has been reduced by 26 hm3 in the last 50 years.

Box 1. Increased sedimentation rates and erosion of resilience in the marsh

Sedimentation rates in the Doñana marsh have increased dramatically during last few decades, producing resilience loss and undesired regime shifts in ecosystems. Some drivers of this process can be traced back to afforestation practices led by the Romans in the Guadalquivir river basin.
Nevertheless, sedimentation/erosion problem in the Doñana marsh is primarily the consequence of relatively recent events, namely, 1) channelling of the water courses discharging at the march and consequent speeding up of water flows, 2) land use change to agriculture entailing removal of vegetation cover, and 3) removal of grapevine and orchard plantations upwards the marsh promoted by subsidies.
Increased sedimentation is causing the loss in the heterogeneity in the topography of the marsh (reference), leading to the loss of habitats suitable for diverse plant species. This homogenisation reduces response diversity when facing perturbations (droughts, floods, grazing) and thus erodes resilience to buffer disturbance. Seed banks of the soil are considered as key ecosystem components for the resilience of the marsh (reference), due to their capacity to survive after severe drought or floods and to regenerate the pastures of the marsh. Increased sedimentation is contributing to bury the seed bank at a depth they can not germinate, leading to loss of vegetation cover. As vegetation decreases, phosphorus is increasingly released to the water, leading to regime shifts from clear water states to turbid water states. The latter stable state can be considered a less desired one from ecological and economic perspective, as the capacity to provide ecosystem services declines (refugee for

biodiversity, clean water, etc.).

Sediment surface (ha)	25/08/1984	27/09/1996	27/08/1999	19/08/2002
Partido	48,37	90,74	520,44	88,77
Laguna de los Reyes	1,08	0	1,48	0,87
Soto Grande	0	2,26	28,33	14,75
Soto Chico	0	0	7,56	2,97
Canal Mimbrales	0	0	2,73	10,03
	49,45	**93**	**560,54**	**117,39**

Increase of fan sedimentation surface in Doñana marshes. Source: (Doñana Biological Station, http://www-rbd.ebd.csic.es/Seguimiento/seguimiento.htm).

5.1.3.3. Fragmentation

The drainage of the marshes has caused **loss of ecological interactions**: the length of dykes and artificial levees in the Doñana wetlands has increased from 25 to 110 km between 1956 and 2006 (to be developed).

5.1.3.4. Alien invasive species

The Mediterranean has been a basin of unceasing exchanges and trials, in which the biological communities change over time through the introduction, surviving and extinction of species, and Doñana is an example of this. However, in the last years the rate of species introduction in Doñana has increased (Fig. 10).

The globalisation of trade and transport will progressively increase the presence of new species. One example of this can be seen in the River Guadalquivir itself, where there are seven introduced fish species. The first to colonise the area were carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) native to Eastern Europe and Asia, probably in the 19th century. In 1921, the Eastern mosquitofish (*Gambusia holbrooki*) was introduced from the United States to fight malaria. Both native to North America, the largemouth bass (*Micropterus salmoides*) and the mummichog (*Fundulus heteroclitus*) were introduced in the 1970s (García-Novo and Marín-Cabrera, 2006). During the heavy rain seasons in 1996 and 1997 the pumpkinseed (*Lepomis gibbosus*) became the last American species to colonise Doñana. Other important aquatic invasive species because the effect on the SES are: the Louisiana crayfish (*Procambarus clarkii*), the red-eared slider (*Trachemys scripta elegans*), and the water fern *Azolla filiculoides*.

Another important alien invasive species is the ruddy duck (*Oxyura jamaicensis*), which was introduced in 1950s from America. It breeds with the local duck (*Oxyura leucocephala*), the white headed duck, which it has displaced. In recent years, a programme for protecting *Oxyura leucocephala* and for eradicating *Oxyura jamaicensis* has been successfully implemented.

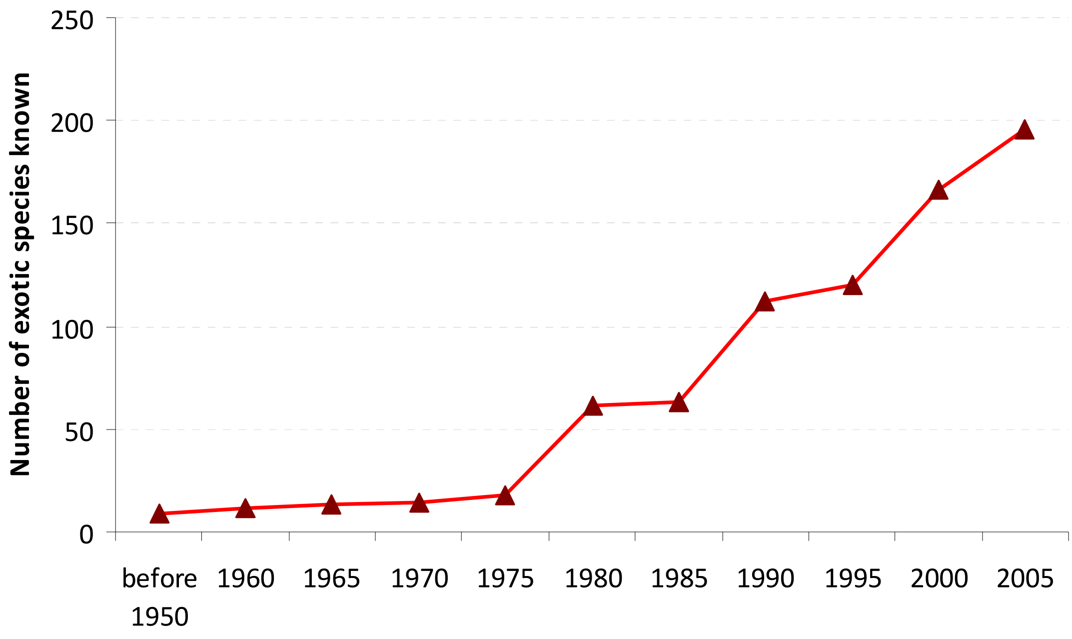


Figure 10. The number of exotic species registered in the scientific literature in Doñana.

Exotic species can replace the native species through competition, predation or parasitism, altering the functional dynamics of the system and, therefore, the provision of ecosystem services. Thus, sometimes the introduction of an exotic species roots on the promotion of one ecosystem services (usually provisioning services). *Eucalyptus* spp. can be an example of this (Box 2).

Box 2. The ecosystem services trade-offs related to the introduction of alien species: the case of Eucalyptus plantations.

The introduction of Eucalyptus (specifically *E. camaldulensis* and *E. globulus*) in Doñana in 1940s supposed a significant impact on many wetlands. These species displace native vegetation through their greater accessibility to groundwater with their deeper roots, causing an appreciable water-table drawdown (of tens of centimetres). This is the case of the El Abalario-La Mediana-La Rocina area, where much of the natural discharge of water-table waters to the Ribetehilos and Mediana wetland complexes, and other isolated lagoons, had completely dried up due to the introduction of eucalyptus trees. Therefore, this event supposed a considerable negative effect on the water provision service.

This serious ecological impact does, however, have different ecological and social benefits. On the one hand, those eucalyptuses that are in Coto del Rey or in the Palacio de Doñana occasionally provide support for the nest of a pair of imperial eagles and for breeding colonies of storks, promoting other ecosystem services, such as the conservation of iconic species. On the other hand, the Eucalyptus plantations supplied different provisioning services (pulp for paper, essential oil, and wood for timber). Also they provided employment in this depressed region for about twenty years and created new settlements where the workers lived with their families. Villages like Los Cabezudos, Bodegones, El Abalario and El Acebuche owe their foundations to the eucalyptus plantations (García Novo and Marín Cabrera, 2006).

Currently, in the new conservationist phase, that from the mid-eighties, eucalyptus plantations were cleared in the National Park and, also, in the Nature Park. However, with this decision the production of honey in Doñana has recently suffered an important decrease (see Figure) because *Eucalyptus* spp. constitutes an important source for nectar, pollen and honey production (Andrés et al. 2006).

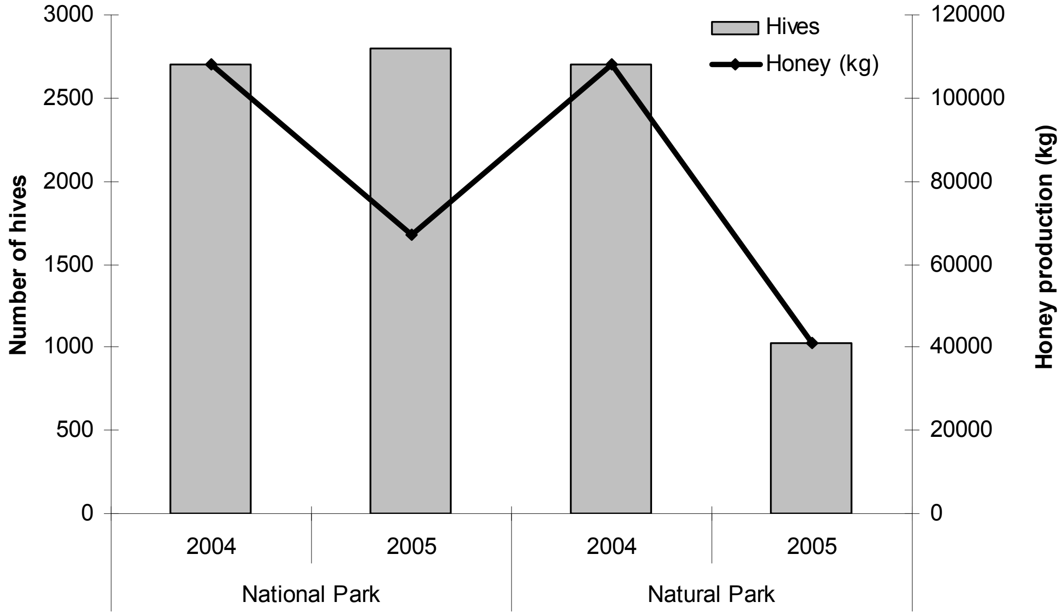


Figure. The decrease of honey production in National and Natural Park of Doñana in the last years.

5.1.4. Maintenance and restoration costs

The budget designated to the conservation of Doñana biodiversity (only species) is one of the most important of all National Parks in Spain (Martín-López & Montes, C., 2007). During the 3-year period 2004-2006, nearly 7.9 € million was dedicated to species conservation. Of this, about 5.1 € million was provided by the Spanish Ministry of Environment, and 2.8 € million by the Department of Environment of the Andalusian government. Despite this significant spending, only a fraction of species conservation needs were funded because resource distribution was skewed toward very few species (Fig. 11).

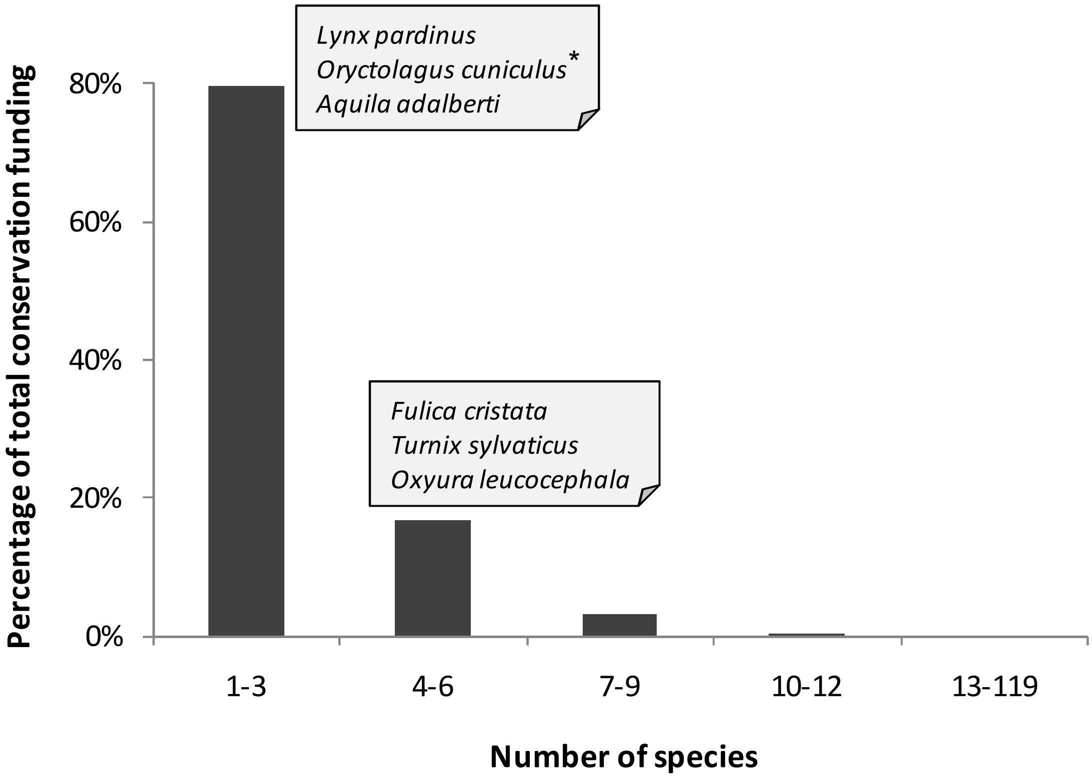


Figure 11. Percentage of conservation funding to endangered fauna species grouped by descending order of expenditures. * Oryctolagus cuniculus is not recognized as endangered species by the Andalusian Red Books, but its conservation interest is because of European rabbit is critically important for conserving Lynx pardinus and Aquila adalberti.(Martín-López & Montes, 2007)

Regarding research funding for biodiversity, nearly 2.9 € million was dedicated to scientific research of biodiversity in the Doñana NPA during 3 years: 2004-2006. Of this, 41.0% was provided by the Spanish Ministry of Environment; 34.2% by the Department of Environment of the Andalusian government, 18.6% by the Spanish Ministry of Education and Science; 5.5% by the Department of Education and Science of the Andalusian government; and 0.7% by the European Union (Martín-López & Montes, 2007).

It is important to note, that Doñana National Park and the Department of Environment of the Andalusian government have focused mostly effort for eradicating and controlling the alien invasive species in Doñana. In this sense, during the last 20 years more than 3.7 € million was dedicated to eradicate or prevent the introduction of alien invasive species. For the last three years, the total amount invested in invasive species in Doñana supposed about 12% of total conservation budget. Similarly, concerning the research, we found that more than 25% of the investigation budget was focused on alien invasive species during 2004-2006 years.

In contrast, higher budget is invested on wetlands restoration projects. The Spanish Ministry of the Environment launched the Doñana 2005 Project in 1998 with the final goal to restore the Park's hydrology (Saura Martínez et al., 2001) as a basis for conservation. It comprises six key interventions addressing specific problems: controlling aquifer overexploitation, building the sewage treatment plant of El Rocío village, reshaping drainage channels entering the Park, recovering degraded areas and purchasing abandoned agricultural lands to restore them, and providing menaced Imperial eagle and Iberian lynx populations with a suitable hunting ground (García-Novo et al., 2007). The average budget spent between 1998 and 2005 on this restoration project was € 83.5 million (UNEP, 2007; http://www.unep-wcmc.org/sites/wh/donana.html). The hydraulic modification of El Partido stream to abate transport of sediments into the Marsh, along with the ecological restoration of its watershed, is the most complex intervention of the Doñana 2005 Project. It has been undertaken by watershed authority (Confederación Hidrográfica del Guadalquivir) belonging to the Spanish Ministry of Environment, with an estimated budget of M€7.85 (García-Novo et al., 2007). Similarly, the ecological restoration of the Guadiamar River Basin through the *Green Corridor and Guadiamar Restoration Project* invested more than 165 € million as a response of one of the most important environmental accidents in Spain –i.e. the rupture of the Aznalcóllar mining dam in 1998-.

Concerning the water quality and quantity research, it is interested to note that the Spanish Geology and Mines Institute (IGME) has invested about 1.9 € million during the last seven years in the research of the aquifer of Doñana (Almonte-Marismas) (Mediavilla et al., 2007).

Box 2. Hidden costs related to ecological degradation: the case of sedimentation

Orchards and grapevines constitute beside cereals, the basis of traditional sustainable agriculture in Doñana. These secular plantations constitute multifunctional land-covers, as beside provisioning services, they perform important cultural (e.g. aesthetic value) and regulating services, especially preventing soil erosion.

At present, Common Market Organizations are subsidizing the removal of grapevine and orchards in the river-basins upwards the marsh, contributing to further increase in erosion and sedimentation rates. Inadecuacy of Doñana's traditional agriculture to compete and create profit in liberalised markets is alleged as the main reason for conducting this policy. Nevertheless, its economic rationality would probably be challenged if externalities and restoration costs related to sedimentation/erosion problems were fully considered in decision making.

Table 5. Summarize of the most important conservation, research and restoration budget invested in Doñana.

		Investment expenditure	Years	Source
Conservation	**Protection of biodiversity (species)**	**7.987.011,94**	**2004-2006**	**Martín-López & Montes (2007)**
Research	**Biodiversity**	**2.903.020,35**	**2004-2006**	**Martín-López & Montes (2007)**
	Alien Invasive species	**923.354,48**	**1990-2006**	**García-Llorente et al. (sumittted)**
	Water quality (aquifer)	**1.895.000,00**	**2000-2007**	**Mediavilla et al. (2007)**
Maintenance and restoration costs of natural resource	**Wetland restoration-water quality**	**108.000.000,00**	**1998-2005**	**Doñana, 2005, UNEP, 2007; http://www.unep-wcmc.org/sites/wh/donana.html**
	Watershed restoration	**165.396.261,58**	**1998-2003**	**Guadiamar Green Corridor programme**
	Fauna and flora (eradication and control of Alien Invasive Species)	**3.765.457,44**	**1988-2006**	**García-Llorente et al. (sumittted)**

5.1.5. Selected socio-economic indicators

5.1.5.1. Population

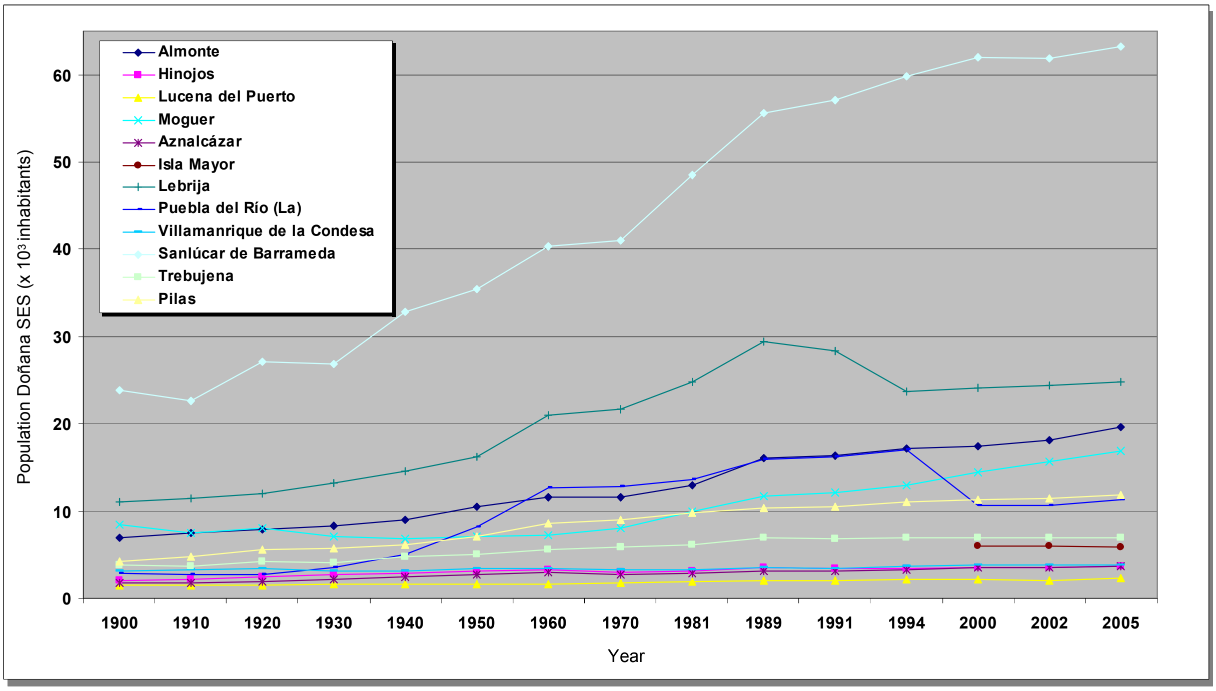
The population of the Doñana SES was of 174.172 at year 2005. The Doñana SES has historically been a feeble inhabited area. This can be partly explained to difficulties to

colonise the territory of the marsh, and partly because the latifundium as dominant property system rendered limited rights to the inhabitants to profit from natural resources.
The Doñana SES had a population 69.517 inhabitants in 1900. This population has been continually growing since 1910 and at present (2005) there are 174.172 inhabitants (Table 6, Fig. 12). This mean a population growth at a rate of 1,43% /year between 1900 and 2005. First large trial of colonisation started in the 19^{th} century, but it was not before the first decades of the 20^{th} century that these trials succeeded. This became possible once the availability of technology and investments permitted the drainage of the marsh and the settlement of crops, especially rice fields.

Table 6. Population growth in Doñana in the 1900-2005 period. Source: Spanish Statistic Institute (INE).

Doñana SES	1900	1920	1940	1960	1981	2000	2005
Almonte	6 917	7 967	8 964	11 538	12 959	17 444	19 641
Hinojos	2 058	2 401	2 908	3 278	3 130	3 556	3 726
Lucena del Puerto	1 456	1 526	1 589	1 703	1 870	2 237	2 283
Moguer	8 455	8 028	6 821	7 222	10 004	14 389	16 961
TOTAL HUELVA	**18 886**	**19 922**	**20 282**	**23 741**	**27 963**	**37 626**	**42 611**
HUELVA province	258 143	331 527	375 180	404 517	418 584	458 998	483 792
Aznalcázar	1 795	1 870	2 454	3 038	2 871	3 518	3 692
Isla Mayor						6 057	5 853
Lebrija	10 997	12 012	14 536	20 937	24 744	24 172	24 866
Pilas	4 251	5 616	6 145	8 604	9 835	11 289	11 918
Puebla del Río (La)	2 841	2 740	5 085	12 612	13 602	10 688	11 326
Villam. de la Condesa	3 079	3 362	3 146	3 392	3 225	3 805	3 826
TOTAL SEVILLA	**22 963**	**25 600**	**31 366**	**48 583**	**54 277**	**59 529**	**61 481**
SEVILLA province	552 455	704 344	957 362	1 244 153	1 478 311	1 734 917	1 813 908
Sanlúcar de Barrameda	23 883	27 103	32 848	40 335	48 496	61 966	63 187
Trebujena	3 785	4 247	4 799	5 591	6 187	6 937	6 893
TOTAL CÁDIZ	**27 668**	**31 350**	**37 647**	**45 926**	**54 683**	**68 903**	**70 080**
CÁDIZ province	450 837	549 710	590 211	812 680	988 388	1 125 105	1 180 817
TOTAL SED	***69 517***	***76 872***	***89 295***	***118 250***	***136 923***	***166 058***	***174 172***

Although population has grown in every municipality of the Doñana SES since 1900, this growth has been uneven when different municipalities are compared. As shown in fig… population growth has been especially fast in Sanlúcar de Barrameda, while municipalities such as Pilas or Hinojos show very moderate growth.



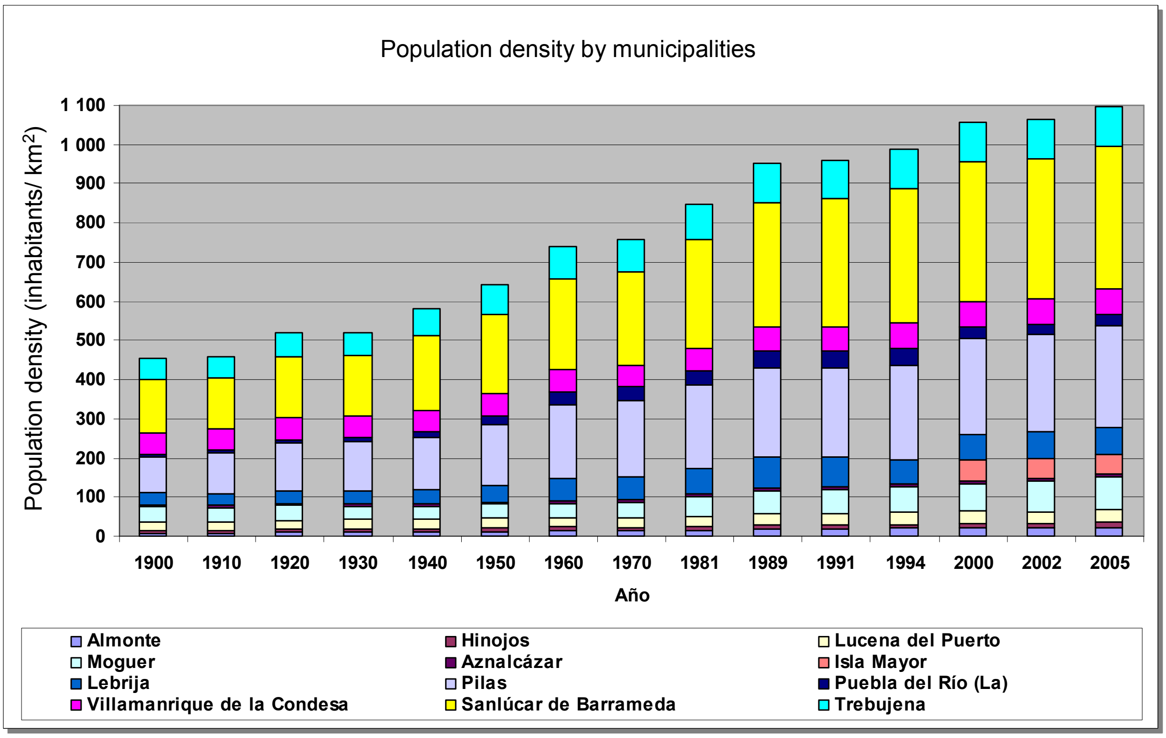


Figure 12. Population growth in the municipalities of the Doñana SES since 1900. Modified from Lomas et al., 2007. Source Andalusian Statistics Institute (SIMA).

5.1.5.2. Employment
Economic activity in the Doñana SES has been continuously growing from the 1980' to the present. Employment in Doñana, which until a few decades ago depended completely on nature, is still strongly dependent the natural capital and ecosystem services of the marsh, estuary, coast, and dunes ecosystems. The rate of employment that is officially employed increased from being 80% at the beginning of the 1980' to about 60% in 2001.

The main economic sectors depending on ecosystem services are agriculture, fishing and aquiculture, cattle farming, forestry, salines and tourism. Nevertheless, more recently industry and housing are gaining weight as economic sectors in Doñana.

5.1.5.3. Provisioning services and employment
Agriculture
Traditional agriculture consists on grapevine, orchards and cereals. Although these crops are still important, rice fields, which started to be cultivated at the end of the 1920's has now become the largest agricultural sector in Doñana. In the 1960's and 1970's the *Plan Almonte-Marismas* promoted the conversion of marsh to intensive irrigated agriculture. The so called "new agriculture", of rice fields, strawberry and other fruits and vegetables is now the engine of the economy based on agriculture. While agricultural surface in Doñana has been increasing all along the 20th century, some traditional crops such as the grapewine are reducing their surface (Table 7 and 8).

Table 7. Crop types and relative importance. Source: Dpto. de Estadística de Sevilla y Huelva. Consejería de Agricultura y Pesca (2001).

Crop types	**Surface (ha)**
Rice	28 922
Orchards	14 755
Cereals	11 477
Industrial crops	9 034
Fodder crops	6 181
Fruits and vegetables	5 463
Vineyards	5 343
Strawberry	4 536
Tuber crops	1 031
Raspberry	545
Leguminous	396
TOTAL	**87 683**

Table 8. Surface (has) of different crop types in the municipalities of the Doñana SES. Source: Dpto. de Estadística de Sevilla y Huelva. Consejería de Agricultura y Pesca. (2001)

Municipality	Cereals	Leguminous	Tuber	Industrial	Raspberry	Fodder	Total
Aznalcázar	5 265	0	0	4 155	0	5 328	14 748
Pilas	256	3	0	264	0	5	528
La Puebla del Río	702	5	41	870	0	15	1 633
Isla Mayor	220	0	0	200	0	450	870
Villamanrique de la Condesa	637	63	704	845	0	0	2 249
Almonte	1 530	294	63	1 060	10	217	3 174
Bollullos Par del Condado	326	5	18	303	0	6	658
Bonares	425	5	10	110	125	15	690
Hinojos	787	7	4	375	0	25	1 198
Lucena del Puerto	327	3	19	145	120	56	670
Moguer	251	6	89	110	250	39	745
Palos de la Frontera	1	0	61	0	0	0	62
Rociana del Condado	750	5	22	597	40	25	1 439
TOTAL	**11 477**	**396**	**1 031**	**9 034**	**545**	**6 181**	**28 664**

Livestock
Since centuries domestic livestock has ranged the Doñana marshes under an extensive grazing system. The quality of the marsh pastures has been acknowledged since the Arabs controlled this territory one thousand years ago (González Fáraco, 1991).
Table 9 presents the number of animals of each municipality in 1999.

Table 9. Livestock statistics in the municipalities of the Doñana SES by species. Source: Censo Ganadero (1999). Unit: Number of animals.

MUNIPALITY	Horses	Caws	Sheeps	Donkeys	Goats	Mules	Avian	Pigs
Almonte	4 388	6 900	3 473	98	1 252	780	63 600	210
Hinojos	766	4 070	1 597	22	470	80	350 000	2 012
Isla Mayor	370	2 179				12		
La Puebla del Río	539	431	4 542	27	125	42	31 000	800
Lebrija	527	12 800	799	67	2 455	92		27 177
Lucena del Puerto	207	1 363	225	11	500	64	29 000	12
Moguer	845	902		31	1 004	102	120 000	465
Pilas	444	85	219	26	144		45 000	326
Sanlúcar de Barrameda	2 216	3 246	4 223	174	1 366	260	107 000	162
Villamanrique de la Condesa		23	783	421	1 525	88	5 899	580
TOTAL		**479**	**15 861**	**10 723**	**8 841**	**1 520**	**37 875**	**31 744**

Currently, the cattle of Doñana is mainly comprised of three native races: the Retuertas horse (*yegua marismeña*), the Doñana feral cattle (*vaca mostrenca*), and the Andalusian churra sheep (*oveja churra lebrijana)* (Calderón Rubiales, 2006). The number of these animals decreases from 6805 (in 1979 year) to 2061 (in 1983) (Rodríguez-Merino and Cobo-García, 2002). In the last five years, the number of individuals oscillates from 3500 (in 2000 year) to 1600 (in 2005 year) (Doñana Biological Station, http://www-rbd.ebd.csic.es/Seguimiento/seguimiento.htm).

On the one hand, these races (especially *vaca mostrenca* and the Retuertas horse) have an important ecological value because their genetic isolation. For instance, the morphological and functional features of Retuertas (e.g. an average height of only 1.42 m and adaptability to hostile marsh environment) are very different from Spanish Pure Breed, Arabian and other Iberian horses of Celtic origin, suggesting genetic isolation of the Retuertas horse population (Vega-Plá et al., 2006). On the other hand, it has also an important historical-cultural value. Every year on the 26th of June a long-held tradition takes place, called the *"Saca de Yeguas"* (The Mares' Roundup), in which the horses that graze in the marshes are herded together and the driven to the El Rocío and Almonte villages in order to cut their manes and tails, as well as sold their foals (Calderón Rubiales, 2006).

Fishing

Along the Guadalquivir estuarine, local people have fished for thousands of years with nets and traps, as well as have collected shellfish along the shores. The marshes and the estuarine of Doñana are of a great interest from a commercial fishing point of view, owing a high market value (Table 10). However, during the last 50 years different fish species suffered a population decrease or extinction, such as the eels or the sturgeons (see Box 3).

Currently, the aquatic communities of the Guadalquivir estuary take on an important social dimension by indirectly contributing to the livelihood of thousands of families. Table 11 and 12 presents the number of fishing boats existing in the estuary and the number of licences of seafood extraction by municipalities, respectively.

Table 10. Fishing in the Guadalquivir estuary and its economic value per year. (Data of Sanlúcar de Barrameda fish market). Source: Agriculture and Fisheries Statistics Yearbook of Andalusia.

Year	Fishes		Mollusc		Crustacean		Total Value (€)
	Weight (Tm.)	Economic Value (€)	Weight (Tm.)	Economic Value (€)	Weight (Tm.)	Economic Value (€)	
1985	3.058,25	4.521	1.127,92	2.232	623,46	2.298	9.052
1986	2.472,00	4.611	1.134,90	2.375	450,00	2.025	9.011
1987	2.566,04	5.320	1.106,88	2.242	494,08	1.855	9.418
1988	2.183,68	4.965	1.009,79	2.325	557,31	2.425	9.716
1989	1.857,87	4.596	748,75	1.970	661,09	3.013	9.579
1990	2.182,32	6.212	791,17	2.145	527,27	3.083	11.439
1991	1.875,73	5.556	788,66	1.753	572,65	3.187	10.495
1992	1.568,26	5.150	734,27	1.590	348,35	2.253	8.993
1993	1.449,86	4.241	780,36	1.519	347,24	2.393	8.153
1994	3.832,53	5.560	910,14	1.678	332,22	3.240	10.477
1995	3.182,74	4.758	1.064,75	1.987	311,97	3.142	9.886
1996	2.039,91	5.773	590,58	1.847	300,06	3.739	11.359
1997	1.912,44	5.999	546,04	1.524	357,62	4.220	11.744
1998	1.797,23	4.862	1.139,18	2.601	413,80	4.451	11.914
1999	1.912,74	5.096	1.022,28	2.514	353,81	4.411	12.022

Table 11. Number of fishing boats by municipalities depending on the estuary. Source: Silva García (2005)

Municipality	Number of fishing boats
Trebujena	90-110
Isla Mayor	60-80
Lebrija	15-25
Coria del Río	10-15
Los Palacios y Villafranca	4
Jerez de la Frontera	1-2
Sanlúcar de Barrameda	1-2

Table 12. Number of licences for seafood extraction by municipalities. Source: Collado Vallejo (2005)

Municipality	Licences
Pilas	71
Sanlúcar de Barrameda	33
Almonte	18
Villamanrique de la Condesa	15
Hinojos	8

Box 3. The Acipenser sturio in the Guadalquivir estuary: the history of a fishing service loss.

Historically, in the Guadalquivir estuary sturgeons (*Acipenser sturio*) were fishing near Sanlúcar de Barrameda. Until the thirties, this species was occasionally caught in the sea by trawlers (Classen, 1944) and by fishing lines near Sanlúcar de Barrameda. In 1932, a dam in Alcalá del Río was finished, at 100 km away from the sea. It represents a barrier to this species because it could not reach the spawning areas above the dam. In the same year, a caviar and smoking plant was opened in Coria del Río (70 km from the river mouth), and an industrially fishing started, gaining an excellent reputation (Fernández-Pasquier, 2000). For a few years after 1932, local fishermen still continued to catch young sturgeons in the estuary using a kind of spoon nets, which also was used for mullets (Mugilidae) catching (Classen, 1944). Consequently, catches close to the dam rapidly declined, while those in the lower estuary increased (Elvira et al., 1991).

Between 1932 and 1972, the capture of 3098 females and 1074 was recorded. The annual evolution of the captures is shown in figure, where a major annual increase in the first years can be seen. In the 1950s, the sturgeon catches suffered a decreasing trend, reaching a critical point in 1962, when captures reduced in less than 20 per year.

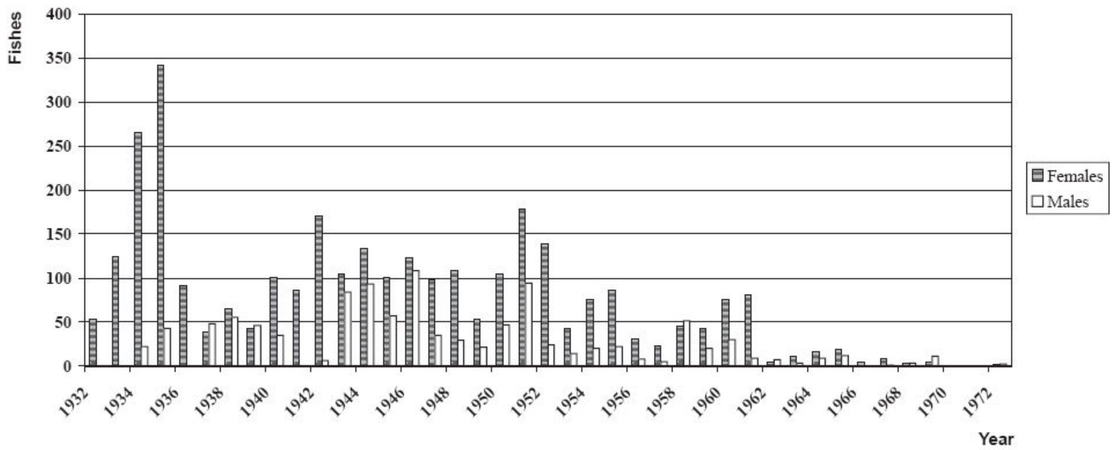


Figure. Annual variation of the number of captured sturgeon fishes. Source: Fernández-Pasquier, 2000.

The factory remained open until 1972, when catches were disappearing. The last records were in 1974 and 1975 (Hernando, 1975) and 1992 (Elvira and Almodóvar, 1993), one fish each year.

Several scientists have blamed the Alcalá Dam as a major cause of decline of sturgeon in the Guadalquivir river (Lozano, 1944), while others have also involved as possible causes the over-fishing in the lower estuary (Classen, 1944), increasing water pollution (Lozano, 1956), and gravel extractions on spawning areas (Gutierrez, 1962). The drastically reduced water flow as a consequence of drought and river regulation could be another important cause limiting the access of individuals to their spawning sites (Fernández-Pasquier, 1999).

Currently, sturgeon is protected by Spanish Law since 1983 and by Andalusian Law since, considering as critically endangered species in the National and Andalusian Red Lists (Granado, C. in CMA, 2001).

5.1.6. Ecosystem services of the Doñana SES

The ecosystems of Doñana perform a diversified flow of ES, from the local (sense of place, hunting, picking up goods, local ecological knowledge) to the national and international scale (carbon sequestration, refugee for biodiversity, research and tourism). The relative importance of each of these services depends thus on the scale at which they are enjoyed (Hein et al., 2006), but also in the valuation criteria (weather it is economic, socio-cultural ecological or other).

Most significant **marketed ES** in Doñana in terms of income are agriculture and aquiculture, beach and nature tourism, science and environmental education (see table 13). *Provisioning services* include agriculture (rice, strawberry, fruits, orchards, vineyards, cereals), and in a smaller extent cattle farming, fishing, seafood, aquiculture, forestry products (wood, pines, scent, honey), and hunting. Most of them are provided outside the protected areas, due to strict restrictions in extractive uses. Most significant *cultural service* is eco-tourism, but science and environmental education are also important indirect sources of income.

Table 13. Physical measurement of some ES in the Doñana wetlands (preliminary results).

Ecosystem services	Quantities	Source
Agriculture	641.947 ton /year	Agriculture and Fisheries Statistics Yearbook of Andalusia
Cattle farming	41.205 animals/ 1999 year	Agriculture and Fisheries Statistics Yearbook of Andalusia
Fishing	2.802 tons/ 2004 year	Agriculture and Fisheries Statistics Yearbook of Andalusia
Tourism	4.092.379 visitors / 2004 year	Martín-López et al. (2007)
Environmental Education	7 large projects	Martín-López & Montes (2007)
Refugee for biodiversity	4.807 recorded sp.	Martín-López et al. (work in progress)

Concerning **non marketed services**, the most significant in the Doñana wetlands are those related to ecological regulation, main *regulating services* performed by the marsh are sedimentary balance, flood prevention, nutrient cycling, waste treatment and refugium for biodiversity. In the case of the estuary, nursery and food web maintenance, waste treatment and erosion control are the most significant. Non marketed *socio-cultural services* include landscape beauty and traditional ecological knowledge, which is being lost as traditional economic activities depending on nature are declining. Spiritual and religious services are also important in Doñana, due to El Rocío pilgrimage that attracts 2 million visitors every year.

Economic valuation of ecosystem services

Economic values of ecosystem services provided by biodiversity in wetlands are not revealed through observable economic transactions and are therefore not measurable through market data (Table 14). Environmental valuation techniques can provide useful evidence to support environmental policies by quantifying the economic value associated with the ecosystem services provided by biodiversity. Table 15 presents the methodology used in order to estimate the economic value of the ecosystem services provided by biodiversity in Doñana, and table 16 summarize the economic value estimated for the most important ecosystem services provided by biodiversity.

Table 14. Degree of integration in markets of the ecosystem services of Doñana

Carrier		Service-type		Category		Service	Full	Partial	None
Production	1	Provisioning	1.1	Food	1.1.1	Hunting		X	
Production					1.1.3	Fishing	x		
Carrier					1.1.5	Livestock		X	
Carrier					1.1.5	Agriculture	x		
Production			1.2	Materials	1.2.4	Fiber crops	x		
Information	2	Socio-Cultural	2.1	Recreational	2.1.2	Ecotourism		X	
Information					2.1.3	Landscape beauty		X	
Information			2.3	Didactic	2.3.1	Education / interpretation		X	
Information					2.3.2	Scientific research		X	
Information					2.3.3	Traditional Ecological Knowledge			x
Regulation	3	Regulating	3.1	Cycling	3.1.1	Soil retention & Erosion control			X
Regulation					3.1.2	Hydrological regulation			X
Regulation					3.1.4	Pollination for useful plants		X	
Regulation					3.1.5	Climate regulation		X	
Regulation			3.2	Sink	3.2.1	Soil purification			X
Regulation					3.2.3	Water purification			X
Regulation			3.3	Prevention	3.3.2	Pest prevention			X
Regulation					3.3.3	Invasive species prevention			X
Regulation					3.3.4	Air quality			x

Table 15. Methods and sources used for the ecosystem services valuation. (WTP = willingness to pay).

Ecosystem service	**Type of Value**	**Type of ES**	**Method of Estimation**
Provisioning	Consumptive direct use value	Crops	Market Analysis
		Cattle	
		Fish	
		Coastal resources	
		Beekeeping	
		Forest resources	
Regulating	Indirect use value		Contingent Valuation (WTP)
		Control of Alien Invasive Species	Restoration Costs Method Conservation Costs Method
		Grazing	Restoration Costs Method Conservation Costs Method
Cultural	Non-consumptive direct use value	Recreational-Tourism	Travel cost method
		Religious values	Contingent valuation (WTP) Travel cost method
		Scientific values	Contingent valuation (WTP) Research Costs
		Educational values	Contingent valuation (WTP)
	Existence value	Aesthetic and spiritual value	Contingent valuation (WTP)

Table 16. Detected economic value of some ecosystem services provided by biodiversity in Doñana.

Type of ES	**Total annual value (2006 €)**	**Source**
Provisioning services		
Agriculture	239 982 510	Agriculture and Fisheries Statistics Yearbook of Andalusia
Sustainable crops	31 102	
Cattle	69 445 529	Agriculture and Fisheries Statistics Yearbook of Andalusia/ Annual Reports of Activities of Doñana National Park
Crayfish fishing	2 811 378	Consejería de Agricultura y Pesca (2001)
Coastal marine resources (inshore and offshore fishing)	11 431 027	Annual Report of Activities of Doñana National Park
Estuary fishing	13 076 100	Agriculture and Fisheries Statistics Yearbook of Andalusia
Wedge shellfishing	1 407 164	
Beekeeping in National Park	127 221	Annual Report of Activities of Doñana National Park
Pine cone harvesting	92 160	Annual Report of Activities of Doñana National Park Annual Report of Activities of Doñana Natural Park
Other forest resources	66 405	Annual Report of Activities of Doñana Natural Park
Total Provisioning Services	**338 439 700**	
Regulating services		
Grazing	12 598	Annual Report of Activities of Doñana Natural Park
AIS control	229 495	García-Llorente et al. (submitted)
Other regulating services	26 004 344	Martín-López et al. (2007)
Total Regulating Services	**26 102 447**	
Cultural services		
Tourism		
Beach tourism	5 940 623	Martín-López et al. (accepted)
Cultural tourism	21 011 629	Martín-López et al. (accepted)
Nature tourism	36 741 776	Martín-López et al. (accepted)
Aesthetic values	85 840 612	Martín-López et al. (2007)
Total Cultural Services	**206 062 000**	
Detected Economic value	**570 604 646**	

Ecosystem services beneficiaries

We define six categories of users: (1) *Environmental professionals* and employees of the Doñana National and Natural Park; (2) those who show interest in nature (*nature tourists*); (3) people who spend just one day in Doñana (*one-day visitors*); (4) visitors looking for cultural heritage sites and events (*culture tourists*); (5) *beach tourists*; and (6) *pilgrims* and other religious visitors (Martín-López et al., 2007).
Environmental professionals are users who come for scientific research or to provide environmental education. *Nature tourists* demand space for recreation and aesthetic enjoyment of natural landscapes, and usually pursue some outdoor activity such as bird-watching. *One-day visitors* are characterized by more passive activities (relaxing, picnicking). *Culture tourists* are people who show interest in the cultural identity of Doñana (traditional practices, local folklore, cultural landscapes, etc.). Their visits usually encompass a broad swath of the Doñana social-ecological system because they try to incorporate both historical and artistic sites (e.g. Colombus' historical places) as well as gastronomy routes. *Beach tourists* mainly want to rest and enjoy the beach. Finally, *pilgrims* converge on the village of El Rocío every year for various cultural festivals directly related to spiritual and religious services. The Pilgrimage of El Rocío and the *Saca de Yeguas* festival, the two largest events, are both focused on El Rocío village. While visitors from all over Spain go on the Pilgrimage of El Rocío to visit the Virgin of El Rocío, *Saca de Yeguas* is mainly attended by people who already live in the Doñana SES.

Trade-offs of ecosystem services among beneficiaries

While biodiversity conservation services were perceived as important by all user categories (>50% rated them most important), the perception of other ES varied by user group. Pilgrims did not attach importance to the supporting-regulating services; in contrast, religious (25% rated them most important) and provisioning (15% rated them most important) services were considered important. Scientific and educational services were considered important by all categories of user; however >10% of environmental professionals rated these as most important (Martín-López et al. 2007; Fig.12).
Regarding the economic value given to ecosystem service, we found that nature and culture users awarded more value to spiritual-aesthetic services, and environmental professionals assigned higher WTP to conserving regulating services. Provisioning services had the opposite trend: users with low levels of environmental behaviour were willing to pay higher amounts than environmentally active users, indicating that perceived utility of certain commodities predominates (Martín-López et al. 2007; Fig.13).

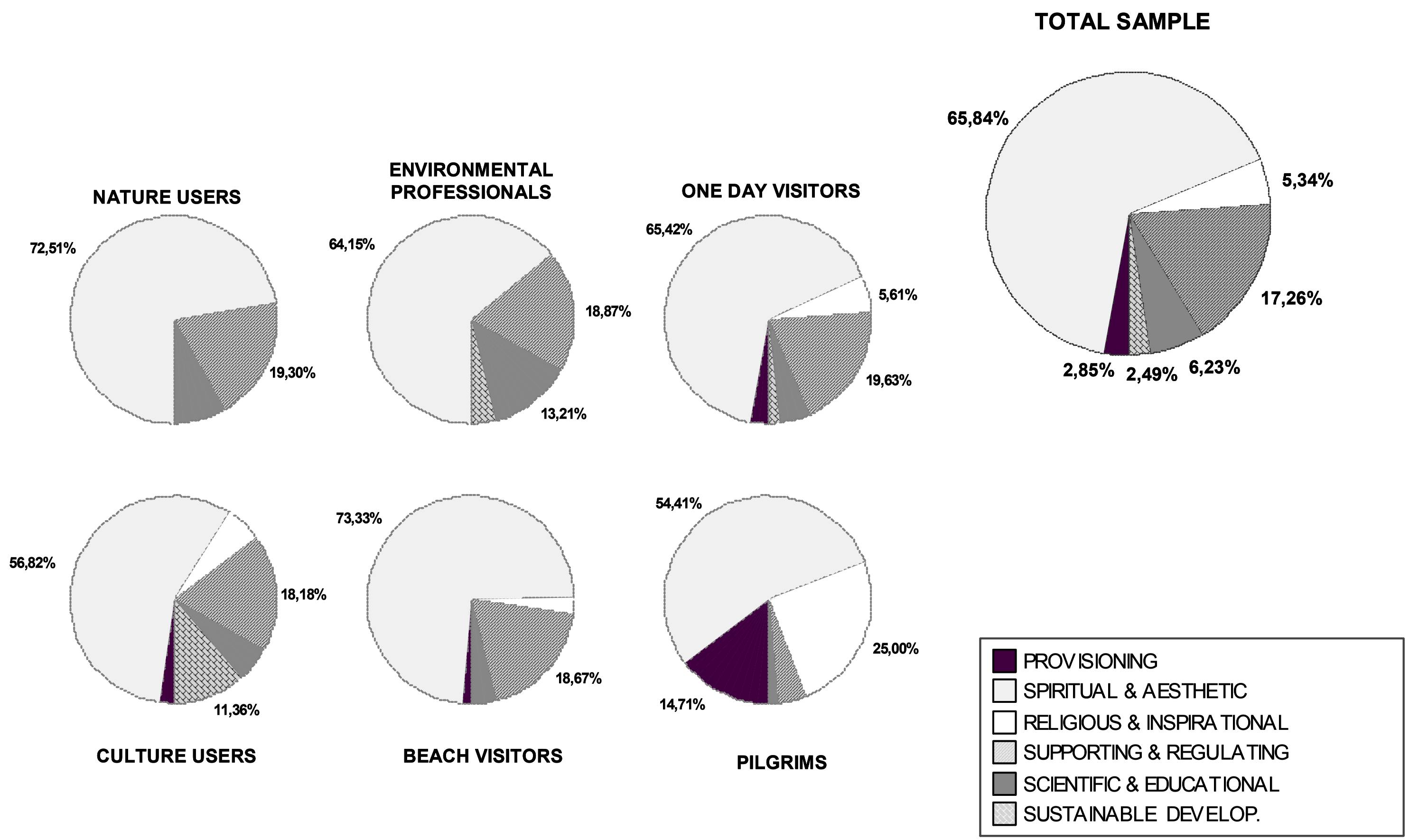


Figure 12. The beneficiaries' perception about the importance of ecosystem services.

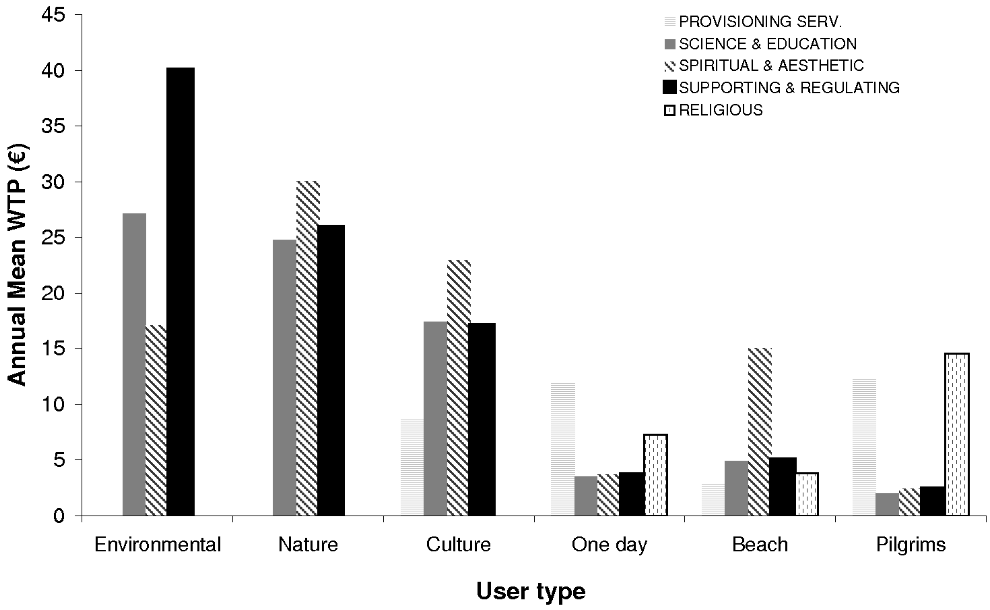


Figure 13. Ecosystem services trade-offs among different beneficiaries in Doñana. Source: Martín-López et al. (2007).

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Doñana: strawberries and rice

"Yet Coto Doñana is still under threat. In a country beset by droughts on a regular basis, the main problem in Doñana is the misuse of water.

Strawberries

In recent years, strawberry farms have sprung up in areas around the park, growing the fruit out of season in response to the demand from northern European consumers for a year-round supply of strawberries. Strawberries are a thirsty crop, and farmers have to extract massive quantities of groundwater, often illegally, to irrigate their plants. This is having a severe impact on the park. Many of the rivers and streams running into Coto Doñana, including one of the most important ones, La Rocina, have experienced reduced flows of up to 50%, leading to a drying out of the wetlands.

The explosion in the number of strawberry farms has also lead to a loss of natural habitat, as many are set up on public land, with the farmers simply clearing the forest illegally to make room for their plants. This is a particular problem when the fields are grown in migration corridors - corridors of natural habitat which provide a vital link for the wildlife of Doñana, including the lynx, to other natural areas."

Rice

"The other main crop related to water in Doñana is rice, which is grown to the east of the National Park. The area was once open marshland, and numerous streams transferred water from the Guadalquivir River to the national park area. Now the streams are gone and the area has effectively been transformed into a vast rice paddy of more than 35.000 hectares of monoculture. The rice farmers recently switched to Integrated Production, thereby reducing many of the environmental impacts of the crop, such as diffuse pollution of chemicals. However, the rice continues to use a lot of water."

"Although artificial in origin, rice paddies in Doñana have become an important habitat for waterfowl. The current situation could be very much improved if the 35.000 hectares of rice paddies were reduced to some extent, thus reducing their water consumption and allowing for a more diverse landscape with a mosaic of uses which would be much more beneficial for biodiversity. Rice paddies could be alternated with natural grazing lands, extensive aquaculture pools or mixed rice/crab production paddies. The environmental impact of the remaining rice paddies could be reduced significantly if the farmers use more efficient irrigation systems and, eventually, switch over to organic farming."

source: WWF/ One Europe More Nature
https://access.eea.europa.eu/get/uri/http://www.panda.org/about_wwf/where_we_work/europe/solutions_programme/one_europe_more_nature/sites/coto_donana/index.cfm